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A
PHILOSOPHICAL INQUIRY
INTO THE
NATURE and PROPERTIES
OF
WATER.
WITH
Elegant Copper-Plate Figures of the ſeveral Salts.

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By J. ROTHERAM, M.D.

> Ιητρικην ὁστις βουλεται ορθῶς ζητειν,————
> δει δε και των ὑδάτων ενθυμεεσθαι τας δυναμιας· ὡϛπερ γαρ εν τω ϛοματι διαφερουσι και εν τω ϛαθμω, ὁυτω και ἡ δυναμις διαφερει πολυ εκαϛου.
> HIPPOCRATES.

> Quam oportet igitur cautos eſſe in inſtituendis cum aqua tam varia experimentis? Quum neceſſario, quaelibet harum, pro variis ſuis contentis, variare debeat omnino effectus inde pendentes. Decet igitur ſcire modos, quibus explorari queat, antequam adhibeantur, puritas.
> BOERHAAVE.

NEWCASTLE UPON TYNE:
Printed by I. THOMPSON, Eſq;
And ſold by J. MURRAY, Bookſeller, in *Fleet-ſtreet*, *London*;
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To
The Revd. Mr. Turner
From his obliged humble Servt.
The Author

BRITISH MUSEUM

To the RIGHT WORSHIPFUL

Francis Forſter, Eſq; Mayor,

To the WORSHIPFUL

The RECORDER and ALDERMEN,

And to the

SHERIFF and COMMON-COUNCIL

Of the TOWN and COUNTY of

Newcaſtle upon Tyne.

GENTLEMEN,

AS in chearful obedience to your commands, I went through moſt of the experiments, which are faithfully

fully related in the following treatiſe; I beg leave to ſubmit it to your candid judgement, and to lay it under your protection.

Allow me at the ſame time to acknowledge my grateful ſenſe of the diſtinguiſhed honour, which I have received, in being appointed to any inſtrumental ſhare in your watchful concern for the true intereſts of this place.

How I have acquitted myſelf in this honourable employment, my private letters have already ſhewn to you; and the following ſheets will declare to the public, who are moſt materially concerned in the reſult.

I can however with great confidence aſſert, that, diveſted of prejudice and un-

unbiaſſed by intereſt, my ſole aim has been the inveſtigation of truth; and that I have not intentionally either concealed or miſrepreſented any thing.

Some people indeed, who would circumſcribe the truth by their own narrow underſtandings, ſubject it to their private views and intereſts, or pervert it according to the ſuggeſtions of malice or envy, I may have offended: The cenſures of ſuch I ſhall ever glory in; and ſhall eſteem it an honour to be found directly oppoſite to thoſe men, who have publickly inſulted the worthy chief magiſtrate of *Newcaſtle*; and falſely aſcribed his benevolent care for the public to ignoble motives.

Convinced, Gentlemen, that, in your *defence* of the public welfare, you will ever *triumph* over all oppoſition; if my endeavours, which have already been honoured by the ſanction of your appointment, ſhould finally meet with your approbation, I ſhall be gratified in the higheſt ambition of,

GENTLEMEN,

Your moſt obedient,

And moſt faithful Servant,

J. ROTHERAM.

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INTRODUCTION.

A

Philosophical Inquiry, *&c.*

THE properties and effects of Water are matters of great and general importance. Whether we conſider this ſubject in a philoſophical, a medical, or œconomical view, we find ourſelves deeply intereſted in the inquiry.

That very able phyſician and philoſopher *Hoffman*, ſays, * "That as Water is properly reckoned by philoſophers amongſt the elements; ſo its extenſive uſe appears through all the works of nature. For, Water is that univerſal ſolvent which divides and tears in pieces the ſolid parts of every kind; imbibes and carries them away with itſelf. From

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* Obſervat. Phyſico. Chemic. lib. II. obſ. 7.

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hence we are furniſhed with a cauſe for the various changes in nature; for without Water, no fertility, nutrition, nor increaſe can take place in the regions of nature. Without Water, no animal lives, no circulation of the blood and humours in the veſſels, no ſecretion, nor excretion of what is uſeleſs can be effected. – If ſolid bodies, as metals, minerals, or ſtones, are to be diſſolved, the help of Water is neceſſary. We ſee no putrefaction, nor corruption, without moiſture; nor can remedies operate upon human bodies; nor fluids act upon ſolids, but by means of Water. Our dry and ſolid food, without fluids, would be deprived of all its uſe and benefit."

The part which this fluid bears in every purpoſe or employment of our lives; not only in the ſeveral trades and manufactures, but in the dreſſing our food, in the cloaths we wear, in the air we breathe, and in all our animal operations, renders it of common, of univerſal importance; and eſſentially neceſſary to our eaſe and convenience, to our health and our lives.

Intending to confine this inquiry chiefly to thoſe Waters which are moſt commonly in uſe; and to ſuch as are moſt fit for ſupplying large towns; I ſhall enter no farther into the general or particular properties of fluids, than this part of the ſubject naturally leads me to. Nor do I mean to addreſs it to philoſophers and phyſicians only; but hope to render it of more general uſe, by adapting it to every capacity, and conducting my experiments and obſervations in ſuch a manner, that every perſon of common underſtanding may be enabled to judge of their propriety, and determine for himſelf; without the neceſſity of having recourſe to the many large volumes which have been written upon the ſubject, by the greateſt men of almoſt every age; ſeveral of which are but in the hands of a few, and in languages which are not univerſally underſtood. I hope likewiſe to relate the experiments in ſuch a manner, that any gentleman, who has leiſure or inclination, may try all or any of them for his own ſatisfaction: Indeed ſome of them are rather tedious; but others, which will often ſhew what Water is fit for general uſe, may be tried without trouble, expence, or inconvenience. And yet I hope that even my learned reader will meet with ſome few improvements which will not be diſagreeable to him.

My experiments are chiefly confined to the Waters in this neighbourhood, of which we have a great variety; and as ſeveral of them are ſimilar to thoſe in other places, theſe experiments may be of more than local utility; and therefore I ſhall relate ſome of them very fully, with the particular circumſtances attending them.

OF WATER IN GENERAL.

THAT Water is the fitteſt for general uſe, which is the pureſt, and moſt free from all heterogeneous particles, or unmixed with any foreign ſubſtance, whether of the animal, vegetable, or mineral kind. An abſolutely pure and unmixed elementary Water we can indeed ſcarcely procure; for whatever bodies it meets with, it will generally carry ſome particles of them along with it; and more eſpecially if it come into contact with any of thoſe ſalts, which are plentifully diſperſed through the animal, vegetable, and mineral kingdoms; even in paſſing through the air, it will attract ſome particles which change its property; and whatever veſſels we keep it in, we generally find a ſenſible change. We muſt therefore be content with that which contains the feweſt of theſe heterogeneous parts, and thoſe of the moſt inoffenſive kind, *i. e.* ſuch as give the leaſt hinderance or diſturbance to its natural operations; more eſpecially ſuch as may be injurious to the animal body, or work any change in the human conſtitution. This, in ſupplying large towns, is a conſideration of great importance; for theſe ſubſtances are often ſo ſmall in quantity, that they operate by ſlow and imperceptible degrees,* and their effects, by this means, may often eſcape the niceſt obſervation; yet, by long and conſtant perſeverance, they may become very prejudicial, if not deſtructive.

Non vi ſed ſæpe cadendo
Gutta cavat lapidem.

That great Philoſopher and friend to mankind, the excellent Mr *Boyle*, found ſuch a variety of different minerals, and ſome of them very miſchievous ones, to lurk imperceptibly in different Waters; that he ſays, it is only by long experience and obſervation that we can be ſatisfied of their ſalubrity: And thoſe who are leſs acquainted with the works of nature, than he was, will readily allow that there are minutiæ which elude our ſtricteſt ſearch, and ſhould teach us not to be too haſty, nor too peremptory in our concluſions. Even poiſons, of the moſt pernicious kind, have been known by experience to be contained in mineral Waters, which were yet ſo ſubtile, that the niceſt chemical analyſis could not diſcover them;[*] we ought therefore to have ſomething more to depend upon, before we pronounce any particular Water ſalutary.

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* See Dr *Percival* on the Waters of *Mancheſter*.

But there are ſeveral Waters which ſhew their properties by manifeſt ſigns; there are likewiſe criteria by which we can often form a tolerable judgment of their comparative purity; and ſeveral good rules are laid down by naturaliſts, to form this judgment, with as much certainty and preciſion, as the nature of the ſubject and our limited comprehenſions will allow.

The firſt and one of the moſt obvious properties is its fluidity; that its parts may be ſeparated with the leaſt known force, and eaſily move amongſt one another. It is needleſs here to enter upon a philoſophical diſquiſition on fluidity, or to conſider upon what form, ſituation, or diſpoſition of particles this property depends. We know that the pureſt Waters yield to the leaſt force, and allow ſolid bodies to move in them with the leaſt reſiſtance. And from hence, if we obſerve any tenacity or clammineſs, we judge that its parts are held together by ſome intervening ſubſtance, and that ſomething beſides Water is contained in it. This tenacity may often be diſcovered by moving the hand or any other body in it; by pouring it out of one veſſel into another, or by obſerving the drops whether they are round and ſmall, or large and pointed.

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[*] Vid. *Hoffman* de venenis.

It is a long eſtabliſhed obſervation, that the beſt Waters boil and cool again the ſooneſt; and that they evaporate in the leaſt time, and with the leaſt degree of heat. Theſe effects are undoubtedly owing, in ſome meaſure, to their more perfect fluidity, by which their parts are more eaſily ſeparated and carried off.

Another appearance in the beſt Waters may partly ariſe from the ſame cauſe; and that is their ſparkling in a glaſs, and forming a number of air bubbles on the ſides of the veſſels which contain them. All Water contains a large quantity of air, or ſome ſubtile elaſtic fluid; and when the preſſure of the atmoſphere is taken off from the ſurface, or conſiderably diminiſhed, ſo as to deſtroy the equilibrium, this fluid will expand, and come out in very great quantities; riſing in bubbles from the bottom of the glaſs, and from every part of the Water, and increaſing in their aſcent; as appears very evidently and beautifully, by putting a tall glaſs of water under a receiver, on the air pump; and by placing two or more glaſſes of different Water, at the ſame time, we often ſee a different effect, and compare one with another.* If the parts of the Water adhere together with any perceptible tenacity, they will not ſo eaſily give way for the expanſion of this fluid; and conſequently when ſuch Water is under an exhauſted receiver, the bubbles will neither be ſo many nor ſo large. And make the Water a little ropy with linſeed, marſhmallow root, gum arabic, or any other mu-

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* *Hoffman* de element. aq. min. recte dijudic.

mucilage, and we ſhall ſcarce ſee one bubble, though we exhauſt the receiver as perfectly as we can.

I would not be underſtood to aſſert that theſe appearances depend wholly upon the degrees of fluidity or tenacity; for *Hoffman*,* Mr *Boyle* and many others have maintained, that there is a ſubtile ætherial ſpirit in Water, which manifeſts itſelf in theſe bubbles: Be it ſo, ſtill our reaſoning holds good; for any viſcidity or ſtrong adheſion of parts, will ſtill prevent the riſing and ſeparating of this ſpirit. Some Waters do indeed contain a very large quantity of ſuch a ſpirit; the pyrmont particularly will ſparkle in the glaſs, and fly like champaign; but this cannot be a mark of its purity, but is rather a proof of a large mixture of ſome particular body in it; and accordingly we find from the proportion of its contents, that it is very far from a ſimple Water; for, upon evaporation, it leaves ſometimes near twenty grains of reſiduum to a pint.† But there are ſeveral Waters, as will be ſeen in the ſequel, which leave ſcarcely a twentieth part of this quantity, and conſequently approach much nearer to a ſtate of purity.

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* loc. citat.

† *Rutty's* Synopſ. p. 315.

Another circumſtance which greatly varies this appearance is the warmth or coldneſs of the Water. All elaſtic fluids which we know are condenſed by cold, and rarefied by heat; conſequently if Water taken directly out of a well, or brought from a cool cellar, be colder than the circumambient air, the ſuperior warmth of the air will expand theſe elaſtic parts, which were before in a compreſſed ſtate, and they will form into numbers of theſe little round bubbles. And when they are urged by a boiling heat, the whole body of the Water is turned into an elaſtic ſteam and flies off, excepting a ſmall proportion of earth or ſalts that remain in the reſiduum.

Upon an attentive peruſal of what *Hoffman* writes upon this point, I am afraid, that great man made his concluſion a little too general; for though ſeveral of the beſt waters, and eſpecially the medicated ones, contain a large ſhare of this elaſtic ſpirit, it will by no means follow that all Waters which abound with it are therefore wholeſome; for there may be, for any thing we know, as great a variety in the qualities of theſe ſpirits, as in thoſe of the fixed parts; the effluvia or volatile parts of ſome Waters are found to be extremely noxious, and a ſtrong poiſon may ſparkle in the glaſs. However we may ſafely conclude that the Water, which exhibits nothing of this appearance, is either originally foul, or has been ill kept, and will never be agreeable to the taſte; which leads me to another obvious teſt of the purity of Water, viz.

That it be entirely free from any particular taſte or ſmell, that it be perfectly inſipid, otherwiſe we may ſafely conclude that it is impure.

It ought likewiſe to be perfectly limpid, bright and tranſparent. Indeed ſeveral good Waters, and eſpecially the river ones, will be muddy and opake, as will be obſerved afterwards; but this can ſcarcely be called an imperfection, if they ſubſide and become clear upon ſtanding; but whatever Water ſhews any particular colour is certainly impure.

OF THE SPECIFIC GRAVITY OF WATER.

ANOTHER teſt of the purity of Water, much inſiſted on, both by the ancients and moderns, is its lightneſs. But though the pureſt Waters may very often be, and perhaps generally are, the lighteſt; yet the ſpecific gravity is not always a certain rule to judge by; for the contents of impure Waters differ much, in ſpecific gravity, amongſt themſelves. Several of the vegetable ſubſtances will ſcarcely increaſe the weight of the Water in which they are infuſed; the mineral ones indeed generally do, but not all in the ſame proportion; for ſome of the ſalts differ from one another, in ſpecific gravity, more than one third; and therefore the ſame quantity of each cannot make an equal alteration in the ſpecific gravity of Water. For inſtance, take an ounce of good alcaline ſalt, and the ſame quantity of purified nitre, and diſſolve them in equal quantities of diſtilled Water; you'll find the two Waters of very different ſpecific gravities, though the quantity of the contents be the ſame in each*. Many of the mineral ſubſtances do indeed add conſiderably to the weight of thoſe Waters which are highly impregnated with them; but in general the difference of ſpeciſic gravity in the Waters in common uſe is not ſo much as many people imagine. *Herodotus* indeed tells us of Water that was ſo light that neither wood, nor even lighter bodies, would ſwim in it. Though *Boerhaave* accounts for this from the weight of the wood, as lignum vitæ and ſeveral of the heavier woods will ſink in our common Waters; yet *Herodotus* evidently means to prove from this, that the *Ethiopian* Waters were much lighter than common; and repreſents to us that ſome of the lighteſt bodies would ſink in them; which ſeems ſcarcely credible, as a piece of dry oak will ſwim in proof ſpirit.

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* It is evident from hence, that a late Author either knew or conſidered very little of the doctrine of ſpecific gravity, when he

Mr *Boyle* tells us* that he had heard of the Water of the *Ganges* being lighter than ours by a fifth part; but in this report he muſt have been

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he ſays in general, that that Water is ſpecifically the lighteſt which when evaporated, leaves the ſmalleſt quantity of reſiduum Experiments made on the Waters in Newcaſtle. p. 2.

* Medicina Hydroſtatica, chap. 14

been impoſed upon; for he ſays immediately after, that "having had, upon ſeveral occaſions, the opportunity as well as curioſity to examine the weight of divers Waters, ſome of them taken up in places very diſtant from one another, I found the difference between their ſpecific gravities far leſs than almoſt any body would expect. And if I be not much deceived by my memory (which I muſt have recourſe to, becauſe I have not by me the notes I took of thoſe trials) the difference between Waters, where one would expect a notable diſparity was but about the thouſandth part (and ſometimes perchance very far leſs) of the weight of either. Nor did I find any difference conſiderable, in reference to our queſtion, between the weight of divers Waters of different kinds, as Spring Water, River Water, Rain Water, and Snow Water; though this laſt were ſomewhat lighter than the reſt. And having had the curioſity to procure ſome Water brought into *England*, if I much miſremember not, from the river *Ganges* itſelf; I found it very little if at all lighter than our common Water."

Profeſſor *Muſſchenbroek*, who has publiſhed the moſt copious table of ſpecific gravities that I have ſeen, makes a difference of $\frac{2}{1000}$ between rain and river Water. But he candidly owns that, in conſtructing his table, he did not always attend very accurately to the degrees of heat, which will in a great meaſure account for this difference*. And I am afraid that many of our tables of ſpecific gravities labour under this defect.

It is much to be lamented that the learned and ingenious Dr *Rutty* has but ſeldom filled up the column of ſpecific gravities, in his very uſeful tables; and, where he has done it, he has uſed the graduated hydrometer; which does not determine the difference in proportion to the whole weight.

Though the ſpecific gravity alone will not determine either the quantity or quality of the contents in Water; yet it is often a good collateral proof, and a conſideration worthy the attention of the curious naturaliſt. And as my method is, ſo far as I know, entirely new, more accurate than any I have ſeen, and eaſily put in practice; I ſhall here give a particular deſcription of it; that any gentleman who chuſes to try it, may fit up the whole apparatus with very little trouble, and at the expence of only a few ſhillings.

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* Introduct. ad Philoſoph. vol. II. p. 536.

FIG. I.

I take an oval glaſs bubble, the body of which (*a*) is about ſeven inches deep, and four in diameter. I load it with ſhot till it ſink in Water to the neck at (*b*). Then taking it out of the Water and drying it, I cement a braſs cap tight upon the neck, ſo that no Water can poſſibly get in. The cap is about an inch and a quarter in diameter, is made rather concave at the top; and has a pointed braſs wire of about an inch long ſoldered into the center of it. The whole, thus fitted up, weighs exactly twenty eight ounces troy; and is light enough to ſwim in the lighteſt Waters.

Immerſing this in a jarr of diſtilled Water I find that a weight of about 46 grains will ſink it till the point of the wire (*c*) comes down juſt to the ſurface of the Water; after which leſs than $\frac{1}{10}$ of a grain added will ſink it to the bottom of the jarr; or $\frac{1}{10}$ taken off will let the point riſe very ſenſibly above the ſurface of the Water. For, when ſo ſmall a part of the wire only emerges, if there be no ſenſible viſcidity in the Water, the ſmalleſt additional weight will carry it down.

Now a quantity of Water, equal in bulk to the whole inſtrument and the weights lying upon it, weighing 13487 grains; I can with certainty determine the comparative gravity of any other Water to leſs than $\frac{1}{134870}$ of the whole; which is much nearer than we can come either by the hydroſtatical balance, or the common hydrometers. And it has this advantage, in common with the hydroſtatical balance, that it ſhews the ſpecific difference in aliquot parts of the whole weight, which the common graduated hydrometer cannot do.

But ſtill a conſiderable difficulty occurs from the expanſion of the Water by heat, a ſmall degree of which will very ſenſibly alter the ſpecific gravity as ſhewn by this inſtrument; I have often found a difference of ſome grains in leſs than an hour; and no thermometer, which I ever ſaw, is carried into diviſions ſmall enough to regulate this inſtrument. Under this difficulty I had no other reſource, than to fix my ſtandard from diſtilled Water, every time I try the experiment. I therefore take a couple of jars, and putting the Water I want to try into one, and diſtilled Water into the other; I let them ſtand together for an hour or more upon the ſame table, till I can pretty reaſonably conclude that they are both of the ſame warmth; then, after balancing the hydrometer exactly in the diſtilled Water, I take it out and immediately put it into the other, by which I find the difference to a very great nicety, and with very little trouble. As by repeated trials I have ſcarce found any difference betwixt the ſpecific gravity of diſtilled Water and filtered rain Water, I now generally uſe the latter.

Another precaution is yet neceſſary; and that is to conſider the ſpecific gravity of the additional weights in the heavier Water, to find the weight of a quantity of Water equal in bulk to them, and ſubtract this from the difference. I make all my grain weights, for theſe experiments, of braſs wire, of a proper thickneſs, and regulate them by an aſſay beam; theſe being more commodiouſly taken up with a pair of forceps, and lying in leſs room than the thin flat weights.

I have never uſed this inſtrument in trying ſpirits, or any fluid but water; though it might be eaſily enough adapted to any of them, by uſing large ſliding weights to remove at pleaſure. But, if it be uſed in ſpirits, the cap muſt not be cemented on with any thing reſinous, as the ſpirits would diſſolve the cement.

Some of the Waters in common uſe will be about twenty grains heavier than rain Water, by this inſtrument; but moſt of them differ only from one or two, to ſix or ſeven grains, and generally come within a thouſandth part of the whole weight, as will in part appear by the annexed table.

OF HARD AND SOFT WATER.

ANOTHER mark of the purity of Water is its ſoftneſs. This is a property of Water which claims one of our firſt and principal regards; as without it the Water would be unfit for moſt purpoſes of life. This quality, as ſtandard from diſtilled Water, every time I try the experiment. I therefore take a couple of jars, and putting the Water I want to try into one, and diſtilled Water into the other; I let them ſtand together for an hour or more upon the ſame table, till I can pretty reaſonably conclude that they are both of the ſame warmth; then, after balancing the hydrometer exactly in the diſtilled Water, I take it out and immediately put it into the other, by which I find the difference to a very great nicety, and with very little trouble. As by repeated trials I have ſcarce found any difference betwixt the ſpecific gravity of diſtilled Water and filtered rain Water, I now generally uſe the latter.

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Some of the Waters in common uſe will be about twenty grains heavier than rain Water, by this inſtrument; but moſt of them differ only from one or two, to ſix or ſeven grains, and generally come within a thouſandth part of the whole weight, as will in part appear by the annexed table.

OF HARD AND SOFT WATER.

ANOTHER mark of the purity of Water is its ſoftneſs. This is a property of Water which claims one of our firſt and principal regards; as without it the Water would be unfit for moſt purpoſes of life. This quality, as it is diſtinguiſhed from what we call hardneſs in Water, is diſcoverable by the touch, if we only waſh our hands in it; and the diſtinction between hard and ſoft Water generally ariſes from its difficult or eaſy union with oily ſubſtances. The ſoft Waters, for this reaſon, diſſolve ſoap more readily, and unite more equally with it; whereas the hard Waters will either not diſſolve it at all, or very imperfectly, and do not mix equally, but curdle. Therefore the ſoft Waters are moſt proper for the waſhing of linen, or any other purpoſe where ſoap is uſed; they will require a leſs quantity of it, and perform their work ſooner. They mix more uniformly with milk, and do not curdle it, as the hard Waters frequently do. They boil peaſe and all legumes ſoft, and mix better with all farinaceous ſubſtances, as rice, flower, oatmeal, &c.

As moſt of our hard Waters contain a mineral ſalt, and a large quantity of earthy or ſtony particles which are united to it, and thus diſtributed through the Water, and mixed moſt intimately with it: *Quere*, Is there not a natural repulſion between theſe mineral ſubſtances and the animal and vegetable oils? Or do they not rather deſtroy or counteract thoſe ſubſtances which are the medium of attraction, or band of union betwixt the water and theſe oils; thereby preventing the ſmall particles of Water from inſinuating themſelves into the pores of theſe oleaginous ſubſtances? And is it not from ſuch inſinuation and ready attraction of its particles, that ſoft Water ſwells and ſoftens all kinds of pulſe in the boiling?

The ſoft Waters are, for the reaſons above aſſigned, generally eſteemed the beſt for making of bread; for bleaching of linen; the making of paper; and for moſt medicinal purpoſes. Likewiſe they are found to be the beſt for boiling of meat, by giving it a more agreeable colour than the hard Waters, which often boil it red. But I ſpeak here only of ſuch Waters as are *eſſentially* ſoft from their purity; not of thoſe which are accidentally ſo from the mixture of an alcali or any other adventitious ſubſtance. Moſt of the alcalious Waters are found to redden fleſh in the boiling; and, what is ſtill worſe, to give it a very diſagreeable ſoftneſs.

There are notwithſtanding ſome purpoſes, to which the hard Waters are adapted; as in ſeveral kinds of dying; in the boiling of greens, to which they give a better colour; in the rinſing of ſoap out of linen, after it has been waſhed, they are obſerved to give the linen a better colour, and an agreeable firmneſs or criſpneſs; but the linen thus treated requires more ſoap when it comes to be waſhed again. Hard Water is likewiſe ſaid to be neceſſary in the making of ſtarch; and every cook-maid knows its uſe in the dreſſing of fiſh, eſpecially cod, which it makes firm and curdles. It has been ſometimes recommended for brewing. The *Burton*, *Nottingham*, *Liverpool*, and ſeveral other kinds of ale which are much admired, are ſaid to be brewed with hard Water. But Dr *Mead* and others condemn the uſe of theſe liqours as productive of various diſorders, and particularly the colic; of which the Dr gives a ſtrong inſtance in the caſe of a lady who was entirely cured of an habitual colic, only by refraining from the uſe of beer brewed with well Water; and whenever ſhe neglected this precaution, her diſorder returned. Indeed from what has been ſaid above, we cannot reaſonably ſuppoſe that hard Water ſhould ſo well anſwer the purpoſes of diluting and digeſting our food; as it will not ſo readily mix and unite with the different parts of it, nor aſſimilate and digeſt them properly. Beſides the large quantities of acid and nitrous ſalts, with the loads of ſelenite and calcareous earth, which theſe Waters generally contain, will naturally diſpoſe them to form obſtructions, when by the courſe of the circulation theſe ſolid particles come into the minuteſt veſſels, more eſpecially thoſe of the glands. Hence they are often blamed as laying the foundation of ſcrophulous, ſtrumous, and other glandular ſwellings and obſtructions.

The *Piedmonteſe*, and other inhabitants about the *Alps*, have long been obſerved to be peculiarly ſubject to theſe kind of complaints; they are taken notice of by *Juvenal*[*] and *Pliny*; and are attributed to the uſe of bad Water. Mr *Sharp* ſays, that theſe tumors are ſo common about Mount *Cenis*, that very few, eſpecially of the women, are exempt from them.[†] It is likewiſe from the large quantity of ſtony matter which the hard Waters generally contain, that moſt of them leave large incruſtations upon the ſides of veſſels in which they are boiled; and they have by ſome been blamed, for this reaſon, as cauſing the ſtone. But the calculous concretions in the bladder and kidneys are of a very different nature from theſe incruſtations; and, as Dr *Heberden* juſtly obſerves, "they totally differ from all foſſil ſtones in every thing, except the name; and the pretended experience of the effects of certain ſtony Waters, in breeding the ſtone, which is often appealed to, may upon the beſt authorities be rejected as falſe."*

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[*] Sat. IX. v. 162.

[†] *Sharp*'s Letters, p. 298, and *Percival*'s Obſ. p. 4.

Though the ſtony incruſtations upon the ſides of veſſels and pipes may be more frequent in the hard Waters; yet, I cannot think this effect wholly peculiar to them, for it is remarkably produced in the boilers of ſome of our fire engines, where the Water is not at all hard, as I ſhall have occaſion to mention more particularly afterwards.

And the Waters at *Carolsbadt* in *Bohemia*, which are known to be ſtrongly alcaline, preſently form a remarkable ſtony cruſt upon any ſolid body that is put into them.*

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* Medical Trans. by the Col. of Phyſ. vol. 1. p. 7.

METHOD OF INVESTIGATING THE PROPERTIES OF WATER.

THE celebrated Mr *Boyle*, and, after him, many learned and judicious authors upon this ſubject, have laid down a multiplicity of rules for judging of the properties and contents of Water; a few of which I have mentioned already, and ſhall now lay down ſuch other methods and precautions as I have obſerved in making the following experiments.

After obſerving what appearances are made at the ſpring head, and in the channel through which the water flows; as whether any ochreous or chalky ſediment be left upon the ſtones; whether the Water has any film or ſcum at the top: I take up a ſufficient quantity of it into clean well corked glaſs bottles, and ſubject it to as many of the following trials as are judged neceſſary.

1. One of the moſt common and eaſieſt methods of judging whether Water contains any con-

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* Phil. Tranſ. vol. 51.

conſiderable mixture of ſaline matter, is to put a little of it into a clean thin glaſs; and having, ready prepared, a ſaturated ſolution of the ſaccharum ſaturni, or ſugar of lead, in clear Water let two or three drops fall into the glaſs: if it make no cloud, milkineſs, nor precipitation, we may be pretty ſure that the Water contains no quantity of mineral ſalt, that we need much regard; for one grain of ſalt, of almoſt any kind, put into a pint of pure diſtilled Water, will diſcover a cloud or wheyiſhneſs upon dropping in a little of this ſolution, and upon ſtanding a few hours will form a thin cruſt upon the ſides of the glaſs. If there be any very conſiderable quantity of acid, alcaline or neutral ſalt, three drops of this ſolution will inſtantly turn a wine-glaſs-full quite turbid and milky; and in proportion to the quantity of the contents, theſe effects will often vary, ſo as to afford an opportunity of forming ſome probable conjecture about them.

This trial is ſo very eaſy and at the ſame time determines ſo quickly the comparative purity of moſt Waters, that it is recommended by almoſt every good author I have read upon the ſubject.

2. Another method frequently practiſed is

by dropping into it a little ſolution of pure ſilver in good aqua-fortis. This trial is ſaid by Dr *Rutty*, to be more touchy than the former one, where it meets with marine ſalt; though Mr *Boyle* ſeems to be of a contrary opinion; for he thinks the ſolution of ſugar of lead is affected with leſs degrees of impurity than the ſolution of ſilver. But the ſilver has undoubtedly this advantage that it will, in ſome meaſure, by the colour of the precipitated ſediment, ſhew the nature of the contents; as this ſediment, is always of a brown or black colour in the ſulphureous Waters, and generally white and grumous in theſe which contain any quantity of marine ſalt. The opacity of the Water in both of theſe experiments is generally proportionable to the quantity of earth it contains; for theſe metallic ſolutions attracting the ſaline parts, which are the band of union between the earth and Water, disjoin the earthy particles & precipitate them. And from all the experiments which I have ſeen or heard related, theſe two methods are ſo very ſimilar that, excepting in the caſe of ſulphur, the effect will generally be the ſame; and as the ſolution of ſugar of lead is more eaſily prepared,

pared, and we may, in moſt caſes, depend upon it; I do not always uſe the other. I would not here be underſtood to aſſert that all Water which ſhews itſelf turbid with one or both of theſe ſolutions is unfit for common uſe; ſeveral Waters may contain a ſufficient quantity of mineral to occaſion theſe appearances, and yet be pleaſant and wholeſome; but whenever theſe effects are obſerved, we may be ſure of ſome mixture, and ſubject the Water to farther experiments. But if Water which is deſigned for common uſe do ſtand theſe teſts, and betrays no foulneſs by its taſte, ſmell, or colour, we may be tolerably ſatisfied with it.

3. Another trial commonly made is by dropping in a little lixivium of tartar; uſually though improperly called the oil of tartar; or a ſolution of any of the alcaline ſalts. If there be any earth ſuſpended by an acid, this will precipitate it; and by this means will generally ſhew a very ſmall degree of hardneſs.

4. But the more uſual and indeed the beſt way of determining the hardneſs or ſoftneſs of Water is by ſcraping any certain quantity of ſoap into it, and obſerving how it diſſolves or lathers. I generally uſe the Caſtile ſoap for

this purpoſe; if Water be perfectly ſoft, the ſoap will diſſolve quickly, uniformly and without curdling; and, upon ſhaking the glaſs briſkly, will raiſe a ſtrong froth or lather at the top; but the ſmalleſt degree of hardneſs will ſhew itſelf, either by the ſoap not diſſolving ſo readily, by its turning curdly and uneven, or by leſs froth remaining after it is agitated; and the different degrees of hardneſs may hereby be very well determined. This is tried the beſt with a ſmall quantity of ſoap, as about a grain to an ounce of Water.

5. Another examination of Water is by mixing the mineral or vegetable acids, and obſerving whether it ferments or turns opake. If theſe effects be obſerved, we conclude that the Water contains either an alcaline ſalt, or abſorbent or calcareous earth; the latter of which will more frequently appear to be the caſe; and Dr *Rutty* ſays that the ſpirit of ſalt is found to be a more ſenſible teſt of either than oil of vitriol.

6. Obſerve whether they change the colour of ſyrup of violets, the blue tincture of the cyanus, or almoſt any other blue flower. An alcaline ſalt inſtantly turns all theſe tinctures to

a full and beautiful green, the abſorbent earths and calcareous nitre likewiſe give them a greeniſh caſt, but not ſo ſtrong, nor ſo quickly; and the colour will vary in its brightneſs or intenſity according to the nature and proportion of theſe ingredients. The mineral acids ſuddenly turn the ſyrup of violets to a bright red; and if the ſyrup be freſh and good it turns red with alum; but Dr *Rutty* obſerves that, when old ſyrup is uſed, it will turn green.

7. Obſerve what tincture the Water extracts from galls, jeſuits bark, or any other vegetable aſtringent. If it ſtrike red or purple, it is a ſure mark of iron; if blue, it ſhews vitriol.

8. By dropping in a little ſolution of quickſilver in aqua-fortis or ſpirit of nitre; or a ſolution of ſublimate in Water; if any of theſe meet with an alcaline ſalt, they drop an orange coloured, yellow, or white precipitate, as the alcali approaches to the lixivial or urinous kind.

9. Mr *Boyle* was very curious in obſerving the different tinges made from the lignum nephriticum; but as I could not conveniently procure that article here, I uſed Dr *Rutty*'s ſuccedaneum for it, the aſh bark; which I have found to anſwer very well, and by the different

blue or green tinctures to ſhew the nitrous or alcaline ſalts.

Mr *Boyle* has mentioned a great many more trials of this kind, as may be ſeen in his memoirs for a natural hiſtory of mineral Waters. But by making theſe mentioned above upon the Waters themſelves, eſpecially when they are tried in concert and compared with one another, we may form a tolerable gueſs of the purity or impurity of Water. And indeed, if Water will ſtand the firſt and fourth teſts, it can ſcarcely be deemed unfit for common uſe.

Yet the curious inveſtigator will not reſt ſatisfied here; but, by diſtilling or evaporating the Water, will ſeparate the volatile from the fixed parts; and thus be more fully ſatisfied both of the quantity and quality of the contents. Theſe experiments are indeed, when duly performed, very tedious, and require much accuracy and patience; but in the end will amply reward all our labour, in their utility and final ſatisfaction.

Dr *Rutty*, to whoſe learning and aſſiduity in this ſubject the world is much indebted, has given us a large collection of theſe experiments which he has performed with great judgement, and related with great perſpicuity. The quantity of Water from which he takes his proportion is the Iriſh gallon, which he tells us is $217\frac{6}{10}$ cubical inches, and $6\frac{4}{10}$ leſs than the Engliſh wine-gallon.

Great exactneſs is neceſſary in fixing the quantity of Water which is ſet to evaporate; for, without this be accurately determined, we can never know the proportional quantity of the contents; and, as Waters differ in their ſpecific gravity, we ſhall ſettle theſe proportions with more preciſion by meaſuring, than by weighing. But the common veſſels by which liquids are meaſured, from their width at the top, are not quite ſo exact as we could wiſh: I therefore uſe the following method, *viz.* I take a common quart bottle with an even neck; and, having exactly weighed it, I fill it with diſtilled Water, and weigh it again when thus filled; by which means I can know, to leſs than a grain, the weight of diſtilled Water in the bottle. The bottle, which I commonly uſe, holds 26*oz.* 11*pwt.* 12 *gr.* or 12756 *gr.* Troy. I then mark the bottle, and preſerve it carefully, for meaſuring the Water which I ſet to evaporate.

I then go upon the ſuppoſition, that an *Engliſh* wine pint of Water weighs a pound Averdupoiſe, or 7000 gr. Troy; if this ſuppoſition be right, it gives the proportion between the ſolid content of our bottle and the wine gallon: But if this ſuppoſition be wrong, it does not affect us; as we ſtill keep to a certain and definite meaſure, which may therefore be reduced to a known meaſure of any other denomination. And when it is found by how much 7000 grains of diſtilled or rain Water are more or leſs than a wine pint, it will ſoon be determined how far the gallon mentioned in the ſubſequent experiments exceeds, or falls ſhort of, the ſtandard wine gallon.

I fill this bottle twice, thrice, or oftener as it is convenient, and put the Water into a wide glaſs, made for the purpoſe, or ſometimes into a glaſed earthen baſon, and ſet it in a gentle heat, either in a ſand furnace, or, which I find anſwers equally well, in a copper plate-warmer before the fire; covering the top of the veſſel with clean paper, and never allowing the heat to be more than I can conveniently bear with my hand. I have found this a neceſſary precaution, for a boiling heat will ſometimes throw off more than half of the reſiduum; and Dr *Rutty* obſerves the ſame in ſeveral of his trials. I find that, by my method, three bottles will generally evaporate in about ſix days.

As in many caſes the quantity of reſiduum is very ſmall; the greateſt care and nicety are requiſite, both in collecting and weighing it. For, as I have ſometimes had but three or four grains from three bottles of Water; if any be loſt, or even a ſmall miſtake be made in the weighing, it throws our proportions wrong; and when theſe proportions are extended to larger quantities, the error will ſwell conſiderably, and become of conſequence. Therefore, when I have but a ſmall quantity, after I have got it well ſcraped and collected together, I weigh it in a pair of well regulated aſſay ſcales, the beam of which will turn, upon occaſion, with the thouſandth part of a grain.*

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* I have never attempted to weigh to greater exactneſs; though ſome beams have been made to turn with a much leſs weight; particularly that of *Merſennus* mentioned by *Muſ-*

But here a difficulty frequently occurs which is not eaſily guarded againſt. For moſt of the reſidua, eſpecially ſuch as contain an alcaline or marine ſalt, attract moiſture from the air ſo faſt, that even during the time of weighing they become ſenſibly heavier. In damp weather, though I have had a fire in the room, I have ſometimes found them increaſe near a fifth part in a few minutes. And this increaſe of weight will ever be in proportion to the dryneſs or moiſture of the air, and the attractive pow-

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Muſſchenbroek (introduct. vol. II. p. 536.) which loſt its equilibrium by adding only $\frac{1}{2548}$ of a grain to either ſcale. And ſome trials of this kind were made a few years ago in England, (as I have been informed by a very learned and ingenious friend) which ran to ſmaller parts of a grain. But theſe extreme niceties are ſcarcely practicable in a ſeries of experiments, from the trouble and difficulty of adjuſting the ſcales every time they are uſed. For, when the ſlide of of the glaſs caſe is lifted up, we cannot always prevent a little moiſture or ſmall particles of duſt from getting to the ſtrings or other parts; which though imperceptible to the eye, will make a ſenſible difference, and often oblige us to regulate the ſcales, before we can pretend to weigh with great nicety. Neither have I found it neceſſary to hang my beam upon diamonds, as ſome are done, and which undoubtedly leſſens the friction; but I take care to have both the axis of the beam and the holes in which it hangs brought to an exquiſitely fine poliſh; which I repair, from time to time, when I find them any way injured.

power of the reſiduum; both which vary greatly in different ſeaſons, and different reſidua. I can form a tolerable judgment of the velocity of this increment, if, after I have brought the beam to an equilibrium, I put a half grain or a grain weight into the ſcale oppoſite to the reſiduum, and obſerve by a ſtop watch how long it will be in fetching it up.

But this, though a pleaſing experiment, does not determine the quantity of moiſture which had been attracted previous to the weighing. Therefore, after the reſiduum has imbibed all its moiſture, and grows no heavier, I weigh five grains of it; and put it upon a clean thick piece of iron made juſt red hot; obſerving whether it crackles and flies, or melts and bliſters, likewiſe whether it flames or ſmokes and what kind of fumes it emits, or whether it has any particular ſmell, or other diſtinguiſhing appearance.

After it has remained a few minutes upon the hot iron, or till it undergoes no farther change; I return it, whilſt hot, and as nimbly as I can into the aſſay ſcales; and, weighing it again, I find what moiſture or other volatile parts it has loſt. And then waſhing it well through two or three glaſſes of diſtilled Water, which I pour off as carefully as I am able, without diſturbing the ſediment at the bottom, I find the exact proportion of calcined earth in five grains of the reſiduum.

I then evaporate the Water which I had poured off, and which I ſuppoſe contains all the ſalt or ſoluble parts; (for if any remain in the ſediment after theſe repeated waſhings, they will be ſo very minute as ſcarcely to deſerve notice) and, when it is brought into a ſmall compaſs, I put it into the hollow of a watch glaſs, and let it ſhoot into cryſtals, which are ready to compare with thoſe produced from the uncalcined reſiduum.*

By theſe means I apprehend that I form a pretty accurate judgement of the proportion between the fixed and volatile parts. But as ſo ſmall a quantity of the reſiduum, from being expoſed to a ſtrong heat, muſt undergo a conſiderable change; we cannot depend either upon the ſalt or earth being the ſame as they were before calcination; indeed they will ſometimes be very different, as ſeveral of the earths will calcine into lime, and ſome of the ſalts will change both their figure and other properties.

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* In ſeparating the earth from the ſalts, I prefer the decanting or pouring very gently off, to filtering, if the earth has perfectly ſubſided and left the Water clear; for ſome parts of the earth adhere to the paper in filtering, which it is almoſt impoſſible to get clean off.

The figure of the cryſtals cannot well be ſeen by the naked eye, and therefore I take the following method: Having preſerved both the calcined and uncalcined ones, in ſeparate watch glaſſes, I can view ſome of them diſtinctly enough with a common magnifier, ſuch as the watchmakers uſe, held in my hand; but the beſt and moſt entertaining method is to put a drop or two of diſtilled Water into the watch-glaſs; and when it is pretty well ſaturated with the ſalt, I take a little of it up with a pointed clean piece of wood, and put it upon the ſlide of my microſcope; and, if there be occaſion, add a little more diſtilled Water, till it be perfectly tranſparent: Then ſcrewing on a pretty large magnifier, and keeping the eye fixed, a beautiful ſcene quickly preſents itſelf; for this ſmall quantity of Water ſoon evaporating, we ſee the cryſtals, from their be-

beginning to ſhoot, till their perfect formation, which in warm weather will generally be compleated in eight or ten minutes.

The figures of the cryſtals here repreſented, as they appeared in the microſcope, were drawn and engraven by my ingenious friends the two Meſſrs *Beilbys*; and I think they have done them great juſtice in the repreſentation.

Though we cannot judge of the nature of a ſalt, by the figure of its cryſtals alone, yet theſe obſervations are both neceſſary and highly entertaining; and without them no analyſis of Water can be completed.

Having reſerved one parcel of the reſiduum entire, and ſeparated the earth and ſalts of another parcel, we can now ſubject each of them to farther inquiries and trials; moſt of which are particularly laid down by Mr *Boyle*, Dr *Rutty* and others, and will be exemplified in the ſubſequent part of this treatiſe. I ſhall therefore, not trouble my reader with a particular relation of them here, but would recommend it to the diligent and impartial inquirer, to try as many of them in concert as he has op-

opportunity; and not precipitately to conclude, or reſt his determination upon fewer trials, when he can have more to build upon. For Waters will agree in ſome reſpects, and differ widely in others: And, in an affair of ſo great conſequence, as determining the good or bad qualities of Waters which are deſigned for common uſe, eſpecially ſuch as we have had no previous experience of, all our diligence and circumſpection is little enough, as ſome properties may ſtill elude our niceſt reſearches.

THE ADVANTAGES OF A LARGE SUPPLY OF WATER.

IN the ſupplying of large towns, we have yet ſomething more than the quality of the Water to attend to. We ſhould take care to provide a ſufficient quantity, not only for domeſtic purpoſes, and the different trades and manufactures, but always to have plenty of Water in ſtore and readineſs, in caſe of fire: And not only ſo, but there ought to be a ſuperfluity, to run conſtantly down the channels in the ſtreets; which contributes to carry away the dirt and filth, prevents any ſtagnating Water from becoming offenſive; and what is of ſtill greater importance, eſpecially in the hot ſummer months, the exhalations from theſe currents cool and refreſh the air; giving not only a very pleaſing ſenſation, but preventing the riſe and ſpreading of malignant and infectious diſorders.* What an agreeable change do we find, when, in a hot ſultry day, we come near the ſide of a brook or rivulet? How inſtantly do we find ourſelves refreſhed, upon the falling of a ſummer ſhower? The air requires a conſtant ſupply and circulation of aqueous particles, to fit it for reſpiration; and in crouded places, where the air is conſtantly vitiated by the breath of the multitude, and other noxious exhalations, the offenſive particles are attracted by, and carried off with, the circulating moiſture. For the ſame reaſon, we find a great advantage from ſetting greens or flowers in pots of Water, and placing them in our cham- 2

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* In the town of *Saliſbury*, they have large currents of Water running down the ſtreets; and in hot weather people are employed to throw it out with ſcoops, and wet the pavement from time to time. And I am told, that the ſame method is practiſed in the ſtreets of *Mantua*, to the great refreſhment of the inhabitants.

bers; the water, which they ſuck up and exhale almoſt at every pore, accompanied with the fragrance of the flowers, produces a moſt agreeable effect. More eſpecially in the chambers of the ſick, or where a perſon is lying in a malignant or any high fever, they are not only of great advantage to the patient, but a ſecurity to his attendants.

That this ſupply of freſh moiſture in the air, has a beneficial effect in curing and ſtopping the progreſs of putrid, malignant and peſtilential diſorders, we have a ſtrong inſtance in the medical hiſtory of *Egypt*, as delivered to us by the learned and elegant *Proſper Alpinus*, who lived and practiſed ſome time at *Grand Cairo*. He tells us,* that epidemical fevers, of the putrid and peſtilential kind, rage annually in this country, from the autumnal ſeaſon till about the middle of *June*: That the plague viſits them about once in ſeven years, making very great havock; that in the year 1580, when he firſt went into *Egypt*, 500,000 perſons died of the plague in *Cairo*, within the ſpace of ſix or ſeven months. He farther acquaints us, that the inhabitants of *Cairo* are attacked in the winter ſeaſon with ophthalmias, or inflammations of the eyes, which increaſe till the beginning of ſummer, when you'll ſee at leaſt fifty out of an hundred labouring under this complaint. About the ſame time the putrid malignant fevers rage much; and particularly that dreadful one, which in the *Arabian* language is called *Dem el muia,* and which he tells us, from the etymology of the word, ſignifies a colliquated ſtate of the blood, and often proves fatal in a very few hours. Theſe, and the peſtilential fevers ſo frequent in thoſe hot and dry countries, are all ſuppoſed to be primarily cauſed by the blood being in too thin and diſſolved a ſtate, and tending to putrefaction; which is forwarded and heightened by the heat of the air, and the want of freſh humid particles: For in this country, they ſeldom or never have any rain. And during the months of *March*, *April* and *May*, they are burnt up by the hot ſcorching winds, which traverſe the vaſt continent of *Africa*; at which time the putrid, peſtilential diſorders rage with the greateſt fury. But as ſoon as the eteſiæ, or periodical northern winds, ſet in, which we are aſſured is always about the time of the ſummer ſolſtice, a great number of black watry clouds fly over every day, from ſun-riſing till about noon; which clouds are ſuppoſed to fall upon the mountains of *Lybia* and *Ethiopia*, and to occaſion the increaſe of the *Nile*: Then the air is cooled and refreſhed by a large quantity of humid particles, brought from the northern ſeas, and all theſe diſorders immediately ceaſe; and thoſe who labour under them generally recover upon the *Nile*'s beginning to riſe.

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* De medicina Egyptiorum. lib. I.

Though rain is ſcarcely ever known in this country, yet it is impoſſible that ſuch a number of clouds can paſs through their atmoſphere without diſtributing a copious moiſture to every part of it; that they do ſo, is evident from the experiment, by which, as *Proſper Alpinus* tells us, the Egyptians judge of the approaching riſe of the *Nile*, viz. They take a little of the mud which was left by the overflowing of the *Nile* the preceding year; and, having carefully dried it, they weigh it, and leave it in the ſcales, in an incloſed dry place; obſerving from day to day how much it increaſes in its weight; and by this increaſe they prognoſticate the height of the future inundation. This earth, or mud, being impregnated with the Egyptian nitre, will attract moiſture very powerfully, and therefore makes not a bad hygrometer, which ſhews undeniably the increaſed humidity of the air at this time.

The overflowing of the *Nile*, which, as the ſame author tells us, happens always about the ſame time, muſt farther increaſe this moiſture, and carry away whatever was ſtagnated and corrupted. For other authors of undoubted credit inform us, that at *Cairo* they have many large common ſewers, which cannot be cleaned out till the *Nile* overflows, before which they become extremely offenſive.

I hope my reader will excuſe this digreſſion, as it is a ſtrong proof of the great effect which a ſupply of freſh moiſture has upon the air; and of the dreadful calamities which attend the want of it. Indeed, without this renovation of moiſture, both animals and vegetables would ſoon periſh; it is, if I may be allowed the expreſſion, the grand circulation of nature; and when it is impeded or deſtroyed, the frame of nature becomes diſordered.

OF RAIN AND SNOW WATER.

RAIN Water is, properly ſpeaking, diſtilled by nature; and though, for reaſons which I ſhall aſſign preſently, it falls a little ſhort of common diſtilled Water in purity; yet, when properly collected and well preſerved, it is of excellent uſe, and ſcarcely inferior to any natural Water which we know. *Boerhaave* calls rain Water the lixivium of the air; and ſays, that in paſſing through the atmoſphere, it collects, and incorporates with various bodies, which fall in its way, as ſalts, ſpirits, oils, ſoaps, earths, and metals themſelves; all which may be raiſed, by different exhalations, into the air, and unite with the aqueous particles, in different proportions according to the ſoil, climate, or various ſeaſons in which they are obſerved. Hence the different degrees of heat and cold, the different winds, meteors, thunder, the ſmoke of furnaces and culinary fires, ſeverally contribute to change the properties of rain Water: In ſummer time particularly it brings along with it the ſeeds and embryos of vegetables and animalcula, which render it diſagreeable to the taſte, and promote its putrefaction.[*]

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[*] Vid. *Boerhaave*'s Chem. tom. I. p. 597.

If it be kept in wooden veſſels it will ſoon ſtink and become unfit for uſe; and then if it be viewed with a microſcope, it is found to contain an amazing number of various animalcules, and particularly thoſe which, from their form and motion, are called the wheel animals.* Theſe animalcula are ſuppoſed to be the chief cauſe of the Water's putrefaction, and therefore *Boerhaave* and others recommend the boiling of it, which will inſtantly deſtroy theſe animals, whether they be perfectly formed, or only in embryo. A ſmall quantity of ſpirit of vitriol added to the Water will likewiſe preſerve it longer from putrefaction.

Rain Water is likewiſe obſerved to be a little hard when it firſt falls;† and I have frequently obſerved it to curdle with ſoap, and turn rather milky with ſugar of lead, when it is newly fallen; but in two or three days it becomes perfectly ſoft.

The rain which falls through the ſmoke of large towns is rendered foul and black; more eſpecially if it be collected, as it generally is, from the roofs of houſes, when it brings with it a great many particles of ſoot, which give it a very diſagreeable taſte and colour: And hence it is that in ſome parts of this town and neighbourhood, where the tiles are conſtantly blackened by the ſmoke of glaſs-houſes, &c. the Water which falls from them is unfit for almoſt any domeſtic purpoſes.

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* *Baker*'s microſcope made eaſy, p. 83, and employment for the microſcope, p. 295. [illegible]

† *Rutty*'s Synopſ. p. 28.

Notwithſtanding all this, I have known rain Water, when properly treated, to be exceedingly pure and good; for, when it ſubſides and is well filtered, it loſes all ſenſible impurity; and in taſte, colour and fluidity, is ſcarcely inferior to any other Water. One of the readieſt and beſt methods of filtering it, is to let it run through a bed of clean ſand, which is preferable to the filtering-ſtone, as it performs its work much ſooner; and the grains of ſand are of ſo many different figures, that they are pretty ſure to ſtop the progreſs of any bodies, of ſenſible bulk, in paſſing through them.*

A friend of mine in this town has a leaden ciſtern for collecting rain Water, ſo conſtructed, that it both allows the Water to ſubſide, and the upper parts of it to run through a bed of ſand, which is raiſed by a partition above the bottom of the ciſtern; by which means the Water becomes perfectly clear and bright, and is preferred, by moſt who have taſted it, to any other Water in this town.

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* If you view a million grains of ſand through a microſcope, you'll ſcarcely find two of the ſame ſize and ſhape.

When Water of any kind is kept in wooden veſſels, it contracts a particular ſmell, taſte and colour from the wood; and our veſſels for this purpoſe being generally made of oak, they may when new, give the Water ſome degree of aſtringency: Therefore clean earthen veſſels are the beſt; though I apprehend leaden ones may be uſed with tolerable ſafety, if they be kept clear from vegetable acids, all of which are found to corrode lead, and to produce a very noxious ſalt. The veſſels in which Water is kept, ſhould likewiſe be covered, to prevent any duſt or filth from getting in; and the Water will be more agreeable if it be kept in a cellar or cool place.

If theſe precautions be obſerved, many families may find great convenience and advantage in collecting and preſerving rain Water, as it will anſwer very well for moſt purpoſes of life, in every reſpect, but the uncertainty of its ſupply.

I have not yet made any particular analyſis of rain Water; as it has, long ſince, been ſo well done to our hands. Dr *Rutty* obſerves, that rain Water, upon ſtanding, depoſites a ſediment nearly the ſame, both in quantity and quality, with that which is obtained by the gentleſt evaporation.* A convincing argument this, of its purity, after ſubſiding and filtering. For, as this ſagacious naturaliſt very juſtly obſerves, the contents are more looſely adherent, or leſs intimately diſſolved in rain Water, than divers others. This obſervation is perfectly conſiſtent with what I have ſaid before of its ſpecific gravity;† for, after repeated trials, I have not found it to differ from that of diſtilled Water more than one hundred thouſandth part of the whole; though I diſtilled the water, which I uſed, in large glaſs veſſels, and with a very gentle heat.

From ſix different ſpecimens of rain Water Dr *Rutty* produced from 6 to 12 grains of reſiduum to a gallon; for the moſt part of a dark brown colour, with ſome particles of white interſperſed; of a bitter, brackiſh, and ſometimes lixivial taſte, and diſagreeable ſmell. From ſeveral experiments he concludes, that this reſiduum is compoſed of calcareous nitre, marine ſalt, ſulphur, and abſorbent earth; each of which ingredients muſt be contained in very ſmall quantities: And when we conſider that the Water thus analyſed, was not previouſly depurated by ſubſiding and filtering; we may reſt pretty well ſatisfied, that rain Water, managed as above directed, will approach as near to a perfect unmixed element, as we can reaſonably deſire; and will ſcarcely be exceeded by any which we can procure, excepting perhaps thoſe from ſnow and hail; which, as they commonly fall in the colder climates and colder ſeaſons, may be leſs affected with thoſe impurities which are occaſioned by heat.

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* Synopſ. pp. 33. 34. 35.

† p. 17.

Some of the greateſt philoſophers and phyſicians have differed much in their opinion of ſnow Water. *Hippocrates* condemns all Water which comes from ſnow and ice, becauſe, he ſays, its fineſt parts are ſeparated and diſperſed by congealing, and only the groſſer ones left.[*] *Hoffman*, who quotes this paſſage, entirely approves the reaſoning, and ſays, that when Water is frozen, its craſis and mixture are evidently deſtroyed: For thoſe conſtituent parts, which are more ſubtile, recede from the coarſer ones, and are driven to the centre, from whence large bubbles are ſeen within any piece of ice, ariſing from the collected air, and cauſing the Water to occupy more ſpace than it did before congelation. And hence, ſays he, it appears manifeſtly, that the fine liquid element being withdrawn, and only the coarſe, groſs and heavy parts left; the Water is by theſe means depraved and corrupted, and cannot but be unwholeſome.[†]

If this reaſoning be juſt, we ſhould naturally conclude, that ſnow Water muſt be ſpecifically heavier than rain, river, or almoſt any other Water; as *Celſus* indeed aſſerts;[‡] and Dr *Rutty*'s experiments make it a little heavier; but I have not been able to find this difference.

Hoffman likewiſe blames ſnow Water for bringing on thoſe glandular tumors and ſwellings of the throat, amongſt the people who live near the feet of mountains covered with ſnow; and inſtances in the inhabitants about the *Pyrenees* and *Alps*, and likewiſe in thoſe of the *Black-foreſt*, *Switzerland*, and *Tirol*. But other authors, with a good deal of reaſon, reject this opinion, and attribute theſe diſorders to another cauſe. They may indeed more probably be owing to the hardneſs and impurity, which the Water acquires in its deſcent from the hills, than to any original bad quality in it.*

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[*] De aerib. aq. et loc.

[†] De Element. aq. § 23.

[‡] lib. 2. cap. 18.

Boerhaave on the other hand is laviſh in his encomiums on ſnow Water, which he prefers to all others: But he adviſes it to be collected carefully from the tops of high ſandy mountains, at a diſtance from any towns or houſes, that it may not be tainted with any ſmoke or other impurities. He likewiſe prefers ſuch as has fallen after a long and ſharp froſt, in calm weather, and takes only the top of it. He ſuppoſes this ſnow to produce the pureſt Water, that art or nature can furniſh us with; that ſcarcely any ſalt, air, oil, or other mixture will be found in it: That it really differs from all other Water; that it is the pureſt of all, quite immutable, may be kept for years, and is a ſingular remedy for inflammations of the eyes.*

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* See p. 23.

This is agreeable to Dr *Rutty*'s account, who collected the ſnow Water which he analyſed in February, after the great froſt in 1739, and followed *Boerhaave*'s precautions as nearly as his ſituation would permit him to do A gallon of this Water left, upon evaporation only four grains of a light brown ſediment, conſiſting of marine ſalt, abſorbent earth, and a pittance of ſulphur.†

Theſe contents appear to be of ſo innocent a nature, and ſo very ſmall in quantity, that we can ſcarce conceive them to have any conſiderable effect, and yet ſome difficulties occur. Whence ariſes the efficacy of ſnow Water in inflammations of the eyes, and in burns? How does it operate in fertilizing the ground? Or whence comes that cruſt or ſtratum, which is formed upon the ſurface of grounds that are frequently covered with ſnow? Theſe are effects told us from the beſt authority, and confirmed by long experience. Can theſe effects be produced, or mechanically accounted for, by the privation of heat, or the action of cold? Or can there be any concentrated ſubtile ſpirit, of the nitrous, or any other kind, which we are totally unacquainted with, and which may have eluded any experimental inquiry? One effect of ſnow, which I can aſſure my reader of, and which I do not remember any where to have read, is, that a certain quantity of it taken up, freſh from the ground, and mixed in a flour pudding, will ſupply the place of eggs, and make it equally light: The quantity allotted is two table ſpoonfulls, inſtead of one egg; and if this proportion be much exceeded, the pudding will not adhere together, but will fall to pieces in boiling. I aſſert this from the experience of my own family; and any one, who chuſes to try it, will find it to be fact. I hope my good natured reader will make allowance for mentioning what, to ſome, may appear trivial; though no appearance in nature is below the notice, or unworthy the attention of philoſophers.

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* *Boerhaave*'s chem. vol. 1. p. 601.

† Synopſ. p. 40 and Table [E E.]

How theſe effects of ſnow can be accounted for, upon the ſuppoſition that it contains little or nothing but pure elementary water, I cannot tell; nor, till I can, will I pretend to decide betwixt ſo great authorities as *Hippocrates*, moſt of the ancients, and *Hoffman* on one ſide; and *Boerhaave*, with moſt of the learned moderns on the other.

Of Spring Water.

As all our ſprings are originally ſupplied by rain, or melted ſnow and hail, ſtrained through the pores and cavities of the earth, their Waters will vary, according to the different ſoils or ſtrata through which they paſs: If Waters meet with nothing in their ſubterraneous paſſages, which will unite with them or diſſolve in them, they iſſue out in their greateſt purity. The ſprings which come from gravel, ſand, or ſome light and porous ſtones are generally the pureſt and beſt; for the Water being filtered through their ſmall pores, is cleared from almoſt every foreign ſubſtance or impurity which it had contracted in the air; acquires an agreeable coolneſs, and becomes limpid, bright and ſparkling.

But as there are few ſoils, which do not contain ſome kinds of ſalt, or other mineral ſubſtances, which are ſoluble in Water; moſt of our ſprings are found to partake in ſome meaſure of the nature of the ſoil through which they paſs. So that, amongſt the almoſt endleſs variety of ſpring Waters, which have undergone the examination of curious naturaliſts, none have been found perfectly pure; but are innocent, ſalutary, or noxious, in proportion to the quantity, kind, or mixture of the various ingredients of which they are compoſed, and the conſtitution of the perſon who uſes them; and ſome of them are found by long experience to be of great medicinal efficacy.

Many of the ſpring Waters in this neighbourhood are affected by the great number of coal-mines, from which an immenſe quantity of Water flows; and ſome of it is highly impregnated with the various ſubſtances it meets with in paſſing through them: The chief and moſt frequent of which is the pyrites, or what our workmen here call braſſes. Prodigious quantities of this are found in moſt of our coal-mines, and employed in ſome very conſiderable copperas works. Moſt of it anſwers to Dr *Hill's* deſcription of the *Gymnopyris varius vireſcens.*[*]

In many of our old workings, where the air has been admitted, a large quantity of vitriol is waſhed away from the pyrites, and mixes with the water; which corrodes all the iron pump rods of the fire-engines, and greatly damages the boilers, or any iron which comes in its way. But when a colliery is newly opened, the water is ſeldom ſo much impregnated with the vitriolic ſalts; the admiſſion of air being neceſſary to their ſeparation from the pyrites.

Indeed this ſalt often ſeems to be interſperſed through the whole ſubſtance of our coals. I have ſome ſpecimens of our beſt coal by me which, out of curioſity, I have kept three or four years in a damp cloſet; between the ſeparating laminæ of which the vitriolic ſalts appear in very beautiful, tranſparent chryſtals; ſome of them white, and others of an elegant golden colour, of an auſtere ſubacid taſte, and totally ſoluble in Water, which they tinge with a beautiful yellow. Theſe ſalts appear in ſpecimens of coal which have no other viſible parts of the pyrites about them; and it is probably from hence, that the dealers in coals judge of their quality by the taſte, and ſay that all good coals taſte of ſalt: But I cannot look upon this to be any criterion of the quantity of bitumen. I have been informed that large quantities of theſe ſalts frequently hang down from the roofs of the workings; from all which it appears evidently, that they are not confined to the pyrites alone, but are, in ſome meaſure, diſperſed through the whole ſtratum.

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[*] Hiſt. of foſſils. p. 614.

As both the coal and pyrites contain a large quantity of ſulphur; it is no wonder that ſome of our Waters ſhould be a little impregnated with it. I have ſeen ſome ſpecimens of the pyrites, in the middle of which, when they were broken, a quantity of ſulphur appeared united to ſome other ſubſtance more friable than the pyrites, and not unlike the coarſeſt kind of auripigmentum: But as I have no ſpecimen of it by me, I have not ſubjected it to any experiments. However there are but a few of our Waters which ſhew any marks of ſulphur, which are diſcoverable by the taſte or ſmell, and when they do, it is generally in a ſmall degree.

Several of our coal Waters are ſtrongly impregnated with iron, and depoſite a thick ochreous cruſt on the bottom, and ſides of the channels through which they run. But the iron is contained in very different proportions, and combined with very different ſalts; as appears from the various colours which the Waters exhibit, when galls are infuſed in them; ſome of them being almoſt red, others purple, a deep blue, black, or green, which laſt is, I believe, generally a mark of the calcareous nitre. We have a fountain in *Gallowgate* of an evident chalybeate taſte; which with galls turns firſt to a faint purple, and after ſtanding twelve hours to a beautiful green.

The ſelenitical, calcareous and abſorbent earths, appear in large quantities, in ſeveral of our coal Waters, ſo as greatly to obſtruct the working of the fire-engines; for they form very thick incruſtations in the large boilers, which are uſed in theſe engines, ſo that in a little time they would be rendered uſeleſs; and therefore when the incruſtation is formed to about the thickneſs of half an inch, our people are obliged to put out the fire, and ſet men

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into the boiler, to clear it out with picks; and in ſome engines they are forced to do this once in a week or ten days; whilſt others will go a month or longer without it. But, what is worthy of obſervation here, is that the tops of the boilers, and the ſteam-pipes, or apertures by which the ſteam riſes into the cylinders, nay the inſide of the cylinders themſelves are all lined by theſe ſtony incruſtations. Thoſe which line the cylinders are indeed an advantage to the working of the engine, for they fill up the little cavities or inequalities; and the conſtant motion of the piſton gives them a poliſh, almoſt as fine as that of glaſs; by which means the piſton is both air-tight, and moves eaſily. I have picked off ſome of this matter from an old cylinder that was nearly as hard as flint. But I mention this here, as a full demonſtration that the earthy or ſtony parts of Water are carried off in great quantities with the ſteam; and therefore, in our analyſes of Water, we ſhould be very cautious of uſing too great a degree of heat.*

Lead is found in moſt parts of this neighbourhood,

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* See page 34.

bourhood, though it has not yet been taken up in ſuch large quantities near this town, as at ſome diſtance from it; yet a few years ago, as I am informed, upwards of ſix tons of lead ore and ſpar were found in the colliery of *Byker*, about two miles from this town: At *Ravenſworth*, *Throckley*, and other places round us, there have been very fair appearances of it; and it is moſtly found in thoſe breaks or interruptions of the ſeams of coal, which are very frequent all through this country, and by our workmen are called dykes. The ſtrata of coal lie nearly horizontal, but generally inclining or dipping towards the ſouth eaſt. But the veins of lead generally run nearly perpendicular, as do the dykes; which leaves great room to conjecture that moſt of theſe dykes may be, if not apparent, yet latent veins of lead, which by croſſing the lighteſt ſtrata of the coal, will throw one part of them ſeveral fathoms above the other; and ſometimes cut them entirely away, to the no ſmall mortification of our adventurers.

Spars and marcaſites of various kinds are found both amongſt our coal and lead ore; but more frequently, and in greater variety, a-amongſt the latter; and ſome of theſe ſubſtances are found, by long experience, to be of a very poiſonous nature. Whether they contain arſenic, as Mr *Boyle*[*] and others have ſuſpected, I pretend not to ſay; but we know well that ſeveral of them, eſpecially when expoſed to the air, are equally noxious with arſenic itſelf, their *modus operandi* equally obſcure, and their effects equally dreadful, though ſometimes more variable. In *Alſton-moor*, *Allen-heads*, *Hexham-ſhire*, *Darwent*, and other places, it is well known that no poultry can live near the waſhings of the lead ore; and this is generally ſuppoſed to be owing to the ſpars, cryſtals, or marcaſites which are waſhed away from the ore, and either picked up by the fowls in ſubſtance, or taken in by means of the Water impregnated with them. This Water is known to injure or deſtroy horſes or other cattle which are unwarily allowed to drink it; and though experience has taught the inhabitants to keep their cattle pretty much from it, yet misfortunes ſometimes happen, ſufficient to keep theſe effects within obſervation and memory.

From

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[*] Experimental Hiſt. of Mineral Waters. § IV. art. 13.

That theſe cryſtals and ſpars have been in a fluid ſtate is evident even from their ſhape and ſtructure; and from their daily formation in the roofs of old mines, where they are found to hang down like icicles: And by the experiments of Dr *Hill* it is unexceptionably proved that Spring Water generally contains a much greater quantity of ſpar, than has been imagined; and that a body which has all the properties of true cryſtal will riſe by heat in the common method of diſtillation.*

It does not at all affect our preſent argument, whether theſe ſubſtances be diſſolved in Water or only ſuſpended in it; it is natural to ſuppoſe that the Water from which theſe ſpars and cryſtals are originally formed, and in which the ſubſtance is contained, will probably partake of their properties.

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* This ingenious and indefatigable naturaliſt took ſome Water from various ſprings, and diſtilled it by a glaſs cucurbite of three feet in length with a ſlow fire in a ſand heat; and he ſays it afforded ſuch different quantities of this ſtony matter, as were ſcarce to be conceived; in diſtilling the Water of the ſame ſpring alſo at different times, and with very different degrees of fire, he procured very different quantities of this ſtony matter, and that exactly according to the degree of fire, the ſtrongeſt always affording the ſmalleſt quantity of ſediment, the ſloweſt fire the greateſt.

Upon diſtilling ſome Water from the ſpring in *Hyde Park*, after this manner, three times over, he procured a ſmall quantity of white ſediment from the ſecond diſtillation, but none from the third; and this ſediment appeared, upon repeated experiments to have all the properties of true cryſtal. *Hill*'s Hiſt. of foſſils, p. 156.

From the difficulty which ſome have found in making a perfect ſolution of arſenic in ſimple Water, it has been queſtioned whether any natural ſprings can contain this ſubſtance; nay ſome have ſaid that it is almoſt impoſſible they ſhould.

It is true that Mr *Boyle* did not procure a ſolution of arſenic in ſimple cold Water; the reaſon of which was that he did not purſue his experiments upon it; and, with his uſual goodneſs and candor, he tells us that he was in haſte, and not at all fond of having to do with arſenic; for which reaſon he cauſed that which he had mixed to be preſently thrown out, to prevent dangerous miſtakes; but ſtill thought it a ſubject worthy of further enquiry.*

Dr *Mead* ſays that white arſenic is entirely ſoluble in Water; and if one part of it be ſufficiently boiled in fifteen parts of diſtilled or rain Water, it gives, by evaporation, ſalts of

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* Experimental Hiſtory of Mineral Waters, § IV. art. 13

triangular planes, which unite into octoëdral cryſtals.†

Mr *Baker* ſuppoſes, from comparing ſome of his experiments with this aſſertion of Dr *Mead*'s, that there may be a difference in arſenic; for that he could never procure ſuch a ſolution; and though he boiled ſmall quantities, for a long while together, in much larger proportions of Water, to the conſumption of the greateſt part, he always found moſt of the arſenic at the bottom undiſſolved: Yet he gives an undeniable inſtance of its ſolubility, from the experiments of Dr *Addington*, as related in the trial of the unhappy Miſs *Blandy*. This gentleman boiled ten grains of powdered arſenic in four ounces of Water, which he filtered, divided into five equal parts, and put into as many glaſſes. On pouring into the firſt glaſs a few drops of ſpirit of ſal ammoniac, it threw down a few particles of a pale ſediment. Some lixivium of tartar poured in to the ſecond produced a white cloud, hanging a little above the middle of the glaſs. Strong ſpirit of vitriol poured into the third, made a conſiderable precipitation of a lightiſh coloured ſubſtance, which hardened into glittering cryſtals, ſticking to the ſides and bottom of the glaſs. Spirit of of ſalt poured into the fourth, precipitated a lightiſh coloured ſubſtance. Syrup of violets in the fifth, produced a beautiful pale green colour.*

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† Eſſay on Poiſons.

The great *Linnæus* gives it as a principal characteriſtic of arſenic, that it is *Solubile in aqua calida et aliis liquoribus.*† *Hoffman* and ſeveral others agree in the ſame thing; but it is needleſs to produce more authorities; as it is now univerſally known that arſenic will diſſolve, and that with very little difficulty in boiling Water. That which I have tried comes very near to Dr *Mead*'s proportion; for the Water ſuſpended about a fifteenth part of its weight by boiling: Indeed, after it was filtered and cooled, a conſiderable part was formed into octoëdral chryſtals, which adhered very firmly to the ſides and bottom of the phial; but the water appeared ſtill to be very ſtrongly impregnated with them; it made a quick and large with large precipitation which ſugar of lead; and when evaporated, formed into a great number of cryſtals, which appeared through the microſcope to be moſtly, of the octo dral kind with triangular ſides, but not quite equal nor regular; nor had they all the ſame number of ſides, and ſome of them were quadrilateral priſms terminating in pyramids at each end; as *(a)*. Others were hexangular, and others appeared like two pyramids with triangular ſides joined together at the baſe; as *(c)*; and when collected together by the drying of the Water, they appeared exactly like a piece of the common white cryſtal in our lead mines; as *(b)*.

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* *Baker*'s employment for the microſcope, p. 136.

† Syſtema Natur. tom. III. p. 117.

FIG. xi.

This ſhews that Water will not ſpontaneouſly precipitate the arſenical ſalts, but remain ſtrongly ſaturated with them, though Mr *Baker* ſeems inclined towards a contrary opinion.

As there ſeemed to be much doubt whether arſenic would diſſolve in cold Water, I put an ounce of arſenic into a phial, and poured upon it ſix ounces of diſtilled Water, perfectly cold, and letting it ſtand two days in my window, it appeared rather thick and turbid; part of the arſenic laid like a ſcum on the top, but the greateſt part ſunk to the bottom; upon ſhaking the phial and ſetting it down again, ſome parts of the arſenic ſeemed to aſcend, and others to deſcend. I then filtered it through four folds of ſtrong cap-paper, and it appeared perfectly bright and limpid; and did not, like the decoction of arſenic, depoſite any cryſtals. I then filled a watch-glaſs with this infuſion, and ſet it before the fire to evaporate; as the Water exhaled, the glaſs was covered over with white ſemi-tranſparent cryſtals which, when viewed through the microſcope, appeared of the ſame ſhape with the others, but leſs; and rather more in number, and ſome of them, which, as I apprehend, preſented their ends to the eye, as at *(d)*, appeared with little black ſpots in the middle. I was the more particular in this obſervation, as I do not remember to have ſeen any deſcription or repreſentation of cryſtals from a cold infuſion of arſenic before.

Whether there may not be a difference in arſenic I cannot ſay: That which I uſed, was procured from a worthy honeſt druggiſt in this town; it was not perfectly white, but in the lump, had a yellowiſh caſt, though nothing like what we call yellow arſenic, and when powdered it was nearly white.

Upon mixing one penny-weight of arſenic, and two of ſalt of wormwood, the mixture totally diſſolved in about two ounces of Water, in a very little time, when ſet before the fire, in little more than a blood heat: This ſolution was not near ſo bright when filtered as either the decoction or infuſion; and a little of it evaporated in a watch-glaſs left a dark brown ſediment, which ſeemed totally to diſſolve, when I put a little of it into the microſcope with a drop of diſtilled Water. The cryſtals of this ſolution were different from either of the other, being compounded of the two ſalts, though ſtill ſome few of the arſenical ones appeared detached, whilſt the reſt appeared ſpongy and ramified, as in FIG. xii.

From all this it appears, that arſenic unites more eaſily and readily with Water by the intervention of an alcaline ſalt: That heat facilitates its ſolution: But that a conſiderable quantity of it will diſſolve in pure Water, without any other heat, than that of the common air. May we not then be allowed to ſuſpect, that it may be contained in mineral Waters. Farther, as this poiſon is commonly found amongſt minerals, and if we know that Water comes from grounds abounding in metals, marcaſites, and ſpars; ought we not to be particularly ſuſpicious and doubtful? leſt, upon a few injudicious, imperfect experiments, and inconcluſive reaſoning, we build ſuch a falſe, ſuch a dangerous ſecurity, as may too late bring us to repentance.

Who can pretend to explain, or who knows all the actions of fluids upon mineral ſubſtances? The vitrum antimonii does not diſſolve in white wine, at leaſt no experiment has yet ſhewn that it does; yet a very ſmall quantity of it infuſed in any of the ſharper fermented liquors will diffuſe a ſtrongly medicated, and in ſome caſes a poiſonous, quality through the whole; and yet it loſes no ſenſible part of its weight: If you pour freſh white wine upon the ſame regulus or glaſs of antimony for a thouſand times, if you pleaſe, the laſt ſhall be equally ſtrong with the firſt. Pour on an ounce, a pint, or a gallon, they ſhall all be of the ſame ſtrength and efficacy: An ounce, or an ounce and half, of this infuſion will be ſtrongly emetic; and, in all probability, half a pint of it would endanger the life of the ſtouteſt man: Yet if we attempt to explain how this is done, by what kind of ſolution, by what diſpoſition of parts, or by what mechanical operation, we are loſt in an inextricable labyrinth. Neither can we reaſon any better about the changes which Water may undergo, in paſſing through the ſtrata of different minerals; or what parts it may take either from ſpars, marcaſites, or arſenical ores: Neither can we always determine with preciſion, which of theſe particles, or how many of them, may not immediately injure the conſtitution; or what quantity may not, like a ſlow poiſon, act imperceptibly and unſuſpected. Yet we may ſurely be ſenſible of facts, and be allowed to reaſon from analogy; and when effects are the ſame, we naturally aſſign the ſame cauſe: Upon our perception of the agreement or diſagreement, the ſimilarity or diſſimilarity, of theſe effects, depends all our phyſical knowledge. And whatever concluſions are fairly drawn from experiment, muſt be admitted as true and juſt, or nearly ſo, till other appearances occur, by which they may be confirmed or rendered exceptionable. Theſe rules of philoſophiſing are taken from the great *Sir Iſaac Newton*; and by following them with patience and aſſiduity, we may have daily opportunities of inveſtigating truths of importance. If they be neglected, and our concluſions built upon the ſlippery foundation of aſſumed hypotheſes, we are ſoon bewildered in error, or loſt in blind ſecurity.

I have been the more particular upon this ſubject, becauſe I apprehend that the exiſtence of arſenic in mineral Waters has been by ſome rather too peremptorily denied; becauſe that even the leaſt ground of ſuſpicion, in an affair of ſuch conſequence, deſerves our ſerious attention and diligent inquiry. That this or other minerals ſimilar to it have exiſted in Waters we have ſtrong hiſtorical evidence;* that, from

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* About two leagues from *Paderborn*, in *Germany*, is a treble ſpring called *Methorn* which has three ſtreams; one of which holds much orpiment, &c. and all the birds obſerved to drink of it die. And ſome of this Water, being carried home, was given to hens, after they had eaten oats, barley and bread crumbs, and ſoon after they had drank of it

from ſeveral circumſtances in the mineral hiſtory of this neighbourhood, and from various appearances in the Waters themſelves, we have juſt cauſe to ſuſpect ſome of our ſprings, I ſhall ſhew preſently; and ſhall, without either hopes of favour or fear of reſentment, lay the before public, my impartial, though perhaps defective, inquiry. The benevolent friends of mankind can never be injured by the inveſtigation of truth; the inſolent menaces of thoſe who prefer their own private concerns to the welfare of mankind I ſhall treat with ſcorn, and the illiterate jargon of the ignorant with contempt. The candid reader will excuſe this little ſally of warmth, when I inform him that that my experiments and concluſions have been publicly cenſured before they were known, and, my propoſitions charged with falſehood before they were delivered: But I beg leave to aſſure him farther, that the baſe and ungenerous

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it, they became giddy, reeled and tumbled upon their backs, with convulſion fits; and died with a great extenſion of their legs. Giving them common ſalt after they had drank, they died not ſo ſoon; giving them vinegar they died not at all, but in ſeven or eight days after were troubled with the pipp. *Lowthorp*'s abridgment of the philoſoph. tranſ. vol. II. p. 331.

rous treatment which I have received ſhall not make the leaſt alteration, either in my ſubſequent trials, or the relation of them: Philoſophy knows no ſuch influence; I ſhall therfore immediately proceed to the examination of ſeveral particular ſprings in this neighbourhood; and, as many of them are impregnated with vitriol from the coal-mines, I ſhall begin with one of the worſt.

VITRIOLIC COAL-WATER.

IN the neighbourhood of *Jeſmond* near this town, a quantity of waſte Water* iſſues out; which preſently depoſites a very large ochreous ſediment, changes the colour of the brook into which it runs for a conſiderable way, and covers its ſides and bottom with a thick reddiſh cruſt.

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[*] By the term waſtes, in this country, is generally meant thoſe large ſubterraneous cavities which are left after the working of a colliery is finiſhed, a proper number of pillars being left to ſupport the roof; theſe cavities are ſometimes of prodigious extent, and of a conſiderable height. The engines being removed, theſe cavities are generally filled with Water, for the ſpace of a great many acres; which Water will make its way at the firſt outlet, and is generally called waſte-water.

It has a thick, ſhining party coloured film at the top.

It taſtes very ſtrongly of vitriol and ſteel.

With powdered galls it turned inſtantly to a fine deep blue, and upon ſtanding a little, to a fine black; and upon increaſing the quantity of galls, and bringing them to a due proportion, I doubt not but that it would make tolerable good ink.

With ſolution of ſugar of lead it made a large white precipitation.

With ſolution of quick-ſilver no change.

With lixivium of tartar a ſtrong green precipitation.

It curdles with ſoap but don't lather.

Its ſpecific gravity was to that of rain Water as 135145 to 134720; the difference 425 or about $\frac{1}{317}$ part of the whole.

It left upon evaporation a large orange coloured ſediment, in the proportion of 240 grains to a gallon.

Five grains of this reſiduum put upon the hot iron melted and crackled a little, then left a brown ſubſtance, which weighed 3¼ grains.

After the ſalt was well waſhed out, there remained a ſediment of a dark brown colour which weighed $\frac{879}{1000}$ of a grain.

The ſalt ſeparated from the reſiduum, had rather a greeniſh caſt; taſted highly vitriolic; when it began firſt to cryſtallize, the ſmalleſt parts of it appeared through the microſcope as at (*a a a.*) but afterwards, as theſe parts of it collected together, by the Water's drying, they formed into larger cryſtals, ſome of which were flatten'd parallelopipeds with rhomboidal ſides, and a ſcabrous ſurface as (*b b.*) and others were hexangular priſms with unequal ſides generally appearing broken and jagged at one end, and terminating in an unequal pyramid at the other as (*c c.*) and when a number of theſe were collected together they formed into rows, making angles about the edge of the drop, ſomething ſimilar to thoſe of an irregular fortification.

FIG. V.

I did not ſubject this Water to any farther trials, as I judged thoſe abovementioned ſufficient, to ſhew it improper for almoſt any uſe in life; nor have I yet tried any other of the ſame kind, though we have a number of them in this neighbourhood, and perhaps ſome of them ſtronger of vitriol than this, which do not ſtill come up to the vitriolic Waters at *Shadwell*, *Kilbrew*, the copper ſpring in *Penſylvania*, and others mentioned by Dr *Rutty*; ſome of which produced from 1320 to 3200 grains of reſiduum in a gallon.

COX-LODGE WATER.

AN attempt was made ſometime ago, to open a colliery near the village of *Cox-Lodge*, between three and four miles to the northward of this town: But after they had bored a conſiderable depth to examine the ſtrata, they came to a pretty large quantity of Water; which, finding vent by the bore hole, and being in a low ſituation, iſſued out in a pretty large quantity, *viz.* at the rate of about fifty hogſheads an hour, and was farmed by a company for ſupplying this town; but it remains yet to be determined how far it is fit or unfit for that purpoſe.

This Water as it comes out appears pretty bright and limpid, ſparkles in the glaſs, and ſhews a good many bubbles under an exhauſted receiver.

Its ſpecific gravity upon one trial was to that of rain Water as 1349460 to 1348650 the difference 810 being $\frac{1}{1666}$ of the whole; but upon another trial, which I believe was rather more accurate, it was as 1348959 to 1348145 the difference 814, making $\frac{1}{1657}$ of the whole.

When freſh taken it ſmells and taſtes very ſenſibly of ſulphur; and if it be kept in bottles cloſe corked, it retains this ſmell and taſte for a long time, but if it be expoſed to the air it ſoon loſes it.

With ſpirit of vitriol it makes a ſenſible ebullition but no precipitation.

With powder of galls a bright amber.

With ſyrup of violets a bright ſtrong green

With aſh bark a blue inclining to a deep pea green.

With lixivium of tartar no change.

With a ſolution of ſugar of lead it became immediately white and turbid, and made a large precipitation.

It diſſolved *Caſtile* ſoap readily and ſmooth, without curdling, and lathered well.

I evaporated three ſpecimens of it, taken at different times, viz. the firſt upon the fourth of

October 1769, the ſecond on the twentieth following, and the third on the fifteenth of June 1770. The reſidua being weighed and part of them calcined upon a hot iron, after the manner directed in page 36. a gallon of each produced as follows, viz.

	Wholereſidu.	Calcined do.	Earth.	Calcined ſalt.
Oct. 4.	58,800 *gr.*	27,000 *gr.*	8,320 *gr.*	18,680 *gr.*
ditto 20.	49,504	27,504	8,192	19,312
June 15.	36,872	24,000	6,563	19,840

By which experiments it appears that notwithſtanding the reſidua, chiefly from the different degrees of moiſture, when they had been a little expoſed to the air, were in different proportions; yet the quantity of fixed ſalt in each was very near the ſame. The firſt indeed contains a little leſs proportion of this ſalt than the ſecond; and the ſecond a little more than leſs
the third: It is to be obſerved, farther, that a gallon of the Water, uſed in the firſt experiment, contained almoſt two grains more earth than that in the laſt; to which I aſcribe the different colour and appearance of the reſidua; for the firſt had a pretty full brown hue, the ſecond was ſomething lighter, and the third almoſt white, but they all produced the ſame effects upon the following trials:

They effervesſced very ſtrongly with ſpirit of vitriol, vinegar and lemon juice.

They turned ſyrup of violets to a ſtrong bright green.

When rubbed with crude ſal ammoniac, they emitted a pungent ſmell.

With ſolution of quickſilver a large orange coloured precipitation.

With oil of vitriol great heat and effervescence, plentiful light coloured acid fumes, and a pungent acrid ſmell, but very different from that of the ſtrong ſpirit of nitre, aqua-fortis, or ſpirit of ſalt.

A little of the groſs reſiduum rubbed on freſh mutton and beef turned them to an intenſe dark red upon boiling, and upon comparing it, in different trials, it reddened meat more than the calcareous reſidua from ſome of our hardeſt Waters.

The firſt reſiduum which was procured Oct. 4. melted and rather bliſtered upon the hot iron, but I did not obſerve this appearance in the other two.

Upon ſeparating the ſalts from the earth they bore the proportion of about $2\frac{74}{100}$ to one, in the firſt caſe, $2\frac{37}{100}$ to one in the ſecond, and 3 to one in the third.

The earthy parts in each were of a brown colour, but thoſe of the firſt were the darkeſt, upon calcination they were mixed with white, efferveſced pretty evidently with ſpirit of vitriol, and appeared to conſiſt of about equal parts of abſorbent and calcareous earth.

The ſalts, as they appeared through the microſcope, when they firſt began to cryſtallize, formed into little ſpiculæ, which attracting one another, ſome ran into irregular little figures as thoſe at (*a*) and (*b*). Others of them were collected into faſciculi, as at (*c*). Others were beautifully ramified, as at (*d*), but ſome of theſe branches extended much farther than is repreſented in this part of the figure; and upon the drop of Water evaporating, the greateſt part of the ſalt formed into a ſpongy porous ſubſtance, ſimilar to that deſcribed in Dr *Hill's* account of the natrum*, and which is well repreſented in the figure (*ee*).

FIG. III.

Upon neutraliſing this ſalt with weak ſpirit of vitriol, it formed into cryſtals, not unlike thoſe

of

* Hiſtory of Foſſils, p 387.

of the Glauber ſalt; and, for ſome time after dropping in the ſpirit of vitriol, it emitted an agreeable ſmell, ſomething reſembling that of dulcified ſpirits of nitre, or rather that of freſh currant-jelly.

The reſiduum of this Water corroded the poliſhed braſs diſh of the ſcales in which it was weighed, leaving a number of little black ſpots upon it: And upon boiling a quantity of it in a braſs pan, it produced the ſame effect, but in a greater degree, leaving a thick ruſt upon the ſides and bottom of the pan.

As this Water flows in a mineral country, and through ſtrata which are yet unknown, but which probably contain large quantities of the cryſtal, marcaſites, and ſpars abovementioned; as theſe bodies are either originally formed from the Water, or frequently found to be ſuſpended in it, and to convey a poiſonous quality to it; and as this Water particularly contains a ſalt, by the means of which, arſenic and ſubſtances ſimiliar to it, are more eaſily ſuſpended in Water, and more intimately mixed with it; and as it ſhewed ſome marks of a corroſive quality; I thought it neceſſary to remove

move theſe objections, and uncertainties as far as I well could. I therefore took thirty grains of the reſiduum, and mixing it into balls with oatmeal, I put it down the throat of a young chicken, which I kept in my room the whole day; but it was not apparently diſordered: I fed it repeatedly that day with oats, which it eat as uſual, and ſhewed no ſign of injury, excepting that its excrements were ſoftened more than common, and of a darker colour. It was afterwards fed, for a fortnight or three weeks, along with other chickens of the ſame hatching, was killed at the ſame time with them, and appeared upon the table to be equally fat and in good condition.

This experiment may convince us, that there was no conſiderable quantity, of any thing immediately pernicious, in the reſiduum; for, if there had, we might reaſonably ſuppoſe, that it would have injured ſo young and tender an animal. But yet we muſt not, from hence, carry our concluſions too far; nor can we, I apprehend, juſtly infer, from a ſingle experiment of this kind, that the Water contains nothing in it which may be prejudicial to the human

man conſtitution. For, the ſtomachs of fowls and their manner of digeſtion are widely different from ours; and that which may produce little or no viſible effect upon one trial, may, by frequent repetition and conſtant perſeverance, be found to be of conſiderable and conſpicuous efficacy. Beſides, it does not appear, nor can it appear ſatisfactorily, by any of our experiments, what parts may be thrown off by evaporation, or how far the moſt active particles of mineral poiſons may be volatile: We know that ſome of the vegetable ones are, nay we know that arſenic itſelf is ſo in ſome degree; though indeed upon evaporating a ſolution of arſenic, we find a conſiderable quantity of cryſtals left, yet we cannot poſitively aſſert, that none fly off in vapour; and our experiments and reaſonings are hitherto found inadequate to the comprehenſion of all the properties of mineral poiſons, their manner of operation, or even their mode of exiſtence. But by long experience and obſervation, diſcoveries may be made, which may either confirm or remove our doubts and ſuſpicions; and afford us a better ſecurity than can be expected from a few haſty trials and uncertain conjectures.

The ſalt contained in this Water, both from the figure of its cryſtals, and the experiments made upon it, agrees, in moſt reſpects, with the natron of the ancients. It is manifeſtly alcaline, though it differs very widely from the artificial alcali, and from the calcareous nitre; it will not, when mixed in any proportion which I have tried, coagulate milk, which both the others are known to do; nor could I find by, taſting it, that nitrous coolneſs upon the tongue, which is remarked of the natron. The pungent ſmell which it acquires, upon its being rubbed with ſal ammoniac is as ſtrong, in my opinion, as that procured by the artificial alcali; though I think it does not effervesce ſo ſtrongly with acids; nor have I ever yet obſerved it to run per deliquium, as the artificial alcalies do, though it does attract a good deal of moiſture. However, it will appear from all the experiments above recited, that moſt of its properties are ſimiliar to thoſe of the common fixed alcalies, from whence we may ſafely conclude, that it will have the following effects, in the common uſes of life:

1. It will boil peaſe and other grain ſoft, even

ven more ſo, and in leſs time than rain or river Water.

2. It will boil greens, ſuch as cale, brocoli, &c.. tender and of a good colour.

3. It will make a ſtrong and good coloured infuſion of green tea; but will be attended with this inconvenience, that it will extract moſt of the ſtrength of the tea upon the firſt drawing.

4. It will anſwer very well for the waſhing of linen, and will require leſs ſoap than moſt other Waters in this neighbourhood; but it will not do for rinſing the ſoap out of them, nor for ſtarching, as the linen thus rinſed and ſtarched will contract damp, and become diſagreeably ſoft.

5. It will probably make a ſtrong infuſion of malt, but how it will anſwer in fermentation, I dare not poſitively ſay, having never tried it.

5. It will be apt to boil meat red and ſoft, and to take away the hardneſs and curd of fiſh.

But, as it is propoſed to ſupply many thouſand people with this Water, the moſt important inquiry is what influences it will probably have upon their health and conſtitution; or what effects or changes the daily and indiſcriminate uſe of theſe ſalts will produce in the animal fluids: And as the learned *Boerhaave* has given us a full and conciſe account of the medicinal effects of the alcaline ſalts, I ſhall make no apology for giving it, as nearly as I am able, in the ſenſe and meaning of an author of ſuch undoubted knowledge and authority*.

The firſt effect which, he ſays, the alcaline ſalts have upon the human body is, that they deſtroy the acids, which are few, except in the *primæ viæ*, and of the mild vegetable kind.

2. If they meet with an acid in the human body, they efferveſce, excite bubbles of air, flatulencies and eructations; they return into a neutral ſalt, which being harmleſs, penetrating, aperient, diaphoretic, diuretic and antiſeptic, produces new effects, ariſing from this newly formed ſalt, and not ſo properly aſcribed to the alcalies, though ſubſequent upon their uſe.

3. By the action of this efferveſcence they ſtimulate the nerves, put the animal ſpirits in motion, and change the former motions of the

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* Chem. vol. ii. p. 58.

nerves and ſpirits: Hence they often cure hypochondriacal and hyſterical ſpaſms, and the diſorders depending upon them; as we learn from the famous anti-emetic of Riverius; whilſt the alcali, drank in the act of efferveſcence with lemon-juice, removes the cholera and the moſt obſtinate vomitings, incurable by any other method.

4. They attenuate whatever is connected with the acid: Therefore, when prudently given; they produce a fine effect upon coagulums of milk, and happily reſolve other tenacious ſubſtances.

5. They attenuate whatever is glutinous, oily or fat, and commodiouſly mix it with Water, from hence they are deterſive: And hence, ſpots of greaſe are cleared away by the lixivium of theſe ſalts, as is well known to fullers, waſhers and dyers: Therefore, by their moderate uſe, they clear the chylopoietic laboratory from its glutinous foulneſs.

6. They reſolve the coagulums of the bile, lymph, blood and ſerum; being admitted into the veſſels, and there agitated by the vis vitæ.

7. By their acrid ſtimulus they put in mo-

tion what is inert; hence they promote the urine ſweat and ſaliva, and move the belly.

8. Therefore wherever there is an inert, tough, mucous pituity; a conſequent acidity of the vegetable aliment in the *primæ viæ*; the ſubſtance or effect of an auſtere acid, manifeſted in coagulums; an abounding colluvies of watery ſerum; tenacious pinguious concretions; and the diſorders often ariſing from theſe, the dropſy, jaundice, leucophlegmatia, gout, rheumatiſm, and ſcurvy; theſe ſalts are of very great ſervice; if they be adminiſtered prudently, well diluted, in ſmall doſes and at proper times. That ſpecies of gout, which ariſes from too much acidity, can ſcarce be more happily cured than by the ſparing and long continued uſe of alcaline ſalt: But yet it ought not raſhly to be recommended as an univerſal remedy againſt the gout, becauſe it is prejudicial to ſuch gouty perſons, as are of a bilious conſtitution, and whoſe humors already ſpontaneouſly tend towards a putrid alcali.

9. Their uſe is pernicious in all caſes where the native ſalts begin to degenerate into the acrid, alcaleſcent, putrid kind; and where the

natural oils of our body incline towards an acrid, fœtid, putrid, rancid, volatile diſpoſition; manifeſted by their offenſive exhalations and the high colour of the urine: They are more eſpecially deſtructive when the bile appears to be in this ſtate, and when the humours are too much diſſolved, fluid and tending to putreſcency; hence in the plague they are immediate poiſon; and in inflammations, ſuppurations, gangrenes, mortifications, continued putrid fevers, and diſorders depending upon too great a velocity *(of the blood)* their internal uſe muſt be entirely prohibited.

Dr *Lewis* gives a correſpondent account of the operation of alcalies; and very juſtly anſwers an objection which ariſes from ſome late experiments, in which they were found to reſiſt putrefaction in the fluids and ſolids of dead animals; by ſhowing, that their action upon living animals muſt be very different, as they apparently increaſe the colliquation, with which all putrid diſeaſes are accompanied.*

Dr *Huxham* likewiſe gives us ſome inſtances of the fatal effects of theſe ſalts upon thoſe who have for a long time together taken the ſoap-lees, or the alcalious ſaponaceous hotchpotch of Mrs *Stephens*; and ſays, it evidently appears that the blood by theſe means is diſſolved and becomes putreſcent, and that the urine becomes alcalious.*

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* Mater. Med. p. 481.

A great many more authorities might be produced, were it neceſſary; but I apprehend enough has been ſaid, to convince any rational and unprejudiced perſon, that Water abounding with alcaline ſalts can never be proper for common uſe.

It is of no avail to ſay, as it has been ſaid publicly and repeatedly of *Cox-Lodge* Water, that in ſome caſes it may be beneficial; this is ſurely acknowledging its efficacy as an alcali; and if it has efficacy to do good, by deſtroying the acids or attenuating the viſcid humours; ſurely it muſt have efficacy to do harm, where theſe acids are too few, or theſe humours already too thin. Farther, when uſed by perſons in perfect health, which health moſt certainly depends, in ſome meaſure, upon the due proportion of acids, and the proper texture or conſiſtence of the animal fluids, it muſt deſtroy the equilibrium, and therefore moſt inevitably bring on diſorders. Nor will it be allowed that the quantity of alcali in *Cox-Lodge* Water is too ſmall to produce effects of this kind; for, it will appear that, by conſtant uſe, it muſt and will operate powerfully as an attenuant. The Waters of *Aix-la-chapelle* do not appear to contain a larger proportion of alcali than thoſe of *Cox-Lodge*; and yet they are found, by long taking, to render the urine alcaline, as do thoſe of *Carolsbadt* in *Bohemia.**—If there be a ſufficient quantity of alcali to paſs through the courſe of the circulation, to be ſecreted by the the kidneys, and produce this effect upon the urine; who ſhall ſay that it will not, in ſome degree, attenuate? That it will not diſſolve the blood, diſpoſe it to putrefaction, and bring on or heighten thoſe putrid fevers, dyſenteries, alcaleſcent ſcurvies, and other diſorders, to which the numerous labouring people in this town, from their diet and manner of living, are peculiarly ſubject?

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* Eſſay on Fevers, p. 48.

Every one knows the frequent neceſſity of plentiful diluting in ardent fevers; and if an alcali be indiſcriminately mixed with the neceſſary diluent, what rational phyſician can anſwer for the event? In caſes of internal hæmorrhages, where large draughts of cold Water have been found of ſignal ſervice, the mixture of theſe ſalts would often defeat the intention.

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* Philoſoph. Tranſ. vol. 51. No. 28.

Upon all theſe accounts, and for other objections which might ſtill be made, I apprehend that no intelligent and unprejudiced phyſician will recommend this Water for the common uſe of this town, where the health of upwards of forty thouſand people is at ſtake; more eſpecially as Water which is much more ſimple and pure, better in every reſpect, and much more in quantity can eaſily be obtained. Nor can I believe that a gentleman of Dr *Lewis*'s known learning, great abilities and ſtrict integrity, could ever have been induced publicly to join in ſuch recommendation, had he been fully and impartially informed of ſeveral particulars which, upon account of his diſtance from this place, he could not well be acquainted with.

THE

THE FOUNTAINS IN NEWCASTLE.

OUR public fountains, or pants, as they are uſually called here, are ſupplied from various ſprings in this neighbourhood, the beſt and moſt approved of which come from ſome riſing grounds to the weſtward of this town. I have not as yet had the opportunity to try them all, and they vary ſo much in different ſeaſons, that experiments upon them might be almoſt endleſs; for ſome of them afford tolerably good Water at one time, and in a few days the Water which comes from them will be ſo hard, and loaded with nitre and vitriol, that it is fit for nothing but the waſhing of rooms or other ſuch purpoſes. This difference, I apprehend, ariſes chiefly from the different quantities of rain Water, which happens to be in the ground; for in wet ſeaſons the Water from theſe fountains is generally ſoft, the proportion of nitrous and vitriolic ſalts being leſs; though at all times there is an evident mixture of them: However ſome of them are, in general, tolerably good, as will appear from the following ſpecimen, which is taken from a fountain or pant near to Sir *Walter Blackett*'s houſe in

Pilgrim-ſtreet; and I am informed that many families in the upper parts of the town, and another public fountain or two are ſupplied from the ſame ſpring.

I examined this Water the 12th of laſt July, in a wet ſeaſon. It was limpid and well taſted.

Its ſpecific gravity was juſt the ſame with filtered rain Water.

It made a ſmall white cloud with ſolution of ſugar of lead.

With lixivium of tartar no change.

It diſſolved ſoap uniformly, and lathered well.

It did not change the colour of ſyrup of violets.

A gallon of it, upon evaporation, left $18\frac{936}{1000}$ grains of reſiduum, of a light brown colour, rather of a brackiſh taſte, and attracted moiſture very faſt.

The reſiduum effervеſced ſtrongly with the vitriolic acid, raiſed white fumes, in ſmell reſembling, though not quite the ſame, with thoſe of ſpirit of ſalt.

Five grains upon a hot iron crackled, and run into a light grey lump, very friable; and whilſt warm, weighed $3\frac{52}{100}$ grains, but increaſed very faſt.

The earth in this part weighed $1\frac{48}{100}$, was of a dark brown colour, and neither efferveſced nor diſſolved in ſpirit of vittiol.

The cryſtals, when viewed through the microſcope, were, ſome of them, almoſt equilateral, hexagonal priſms, with ſome little irregular protuberances as (*a*); others were rhomboidal of diflerent ſizes as (*b*); others flattened cubes, with a ſcabrous ſurface as (*c*); and ſome ſmall ſpiculæ, part of which were ſeparate as at (*d*), and others collected into little branches as at (*e*).

FIG. II.

Theſe cryſtals are evidently a mixture of the nitrous and muriatic kind, though none of them, which I have yet ſeen, anſwer perfectly to either *Liſter*'s or *Short*'s deſcription of the calcareous nitre, the cryſtals of which they repreſent as conſiſting of four, five, or ſix unequal parallelogram ſides, terminating at one end in a pyramidal form by plain triangles, and having the other end more obtuſe and cuneiform, and formed by two Plane ſquares as repreſented in (*cc*). But the whole contents of this Water are ſo ſmall, and conſiſting of ſo many different parts, that if we conſider the effect of the perfectly inert earth, or each of

FIG. V.

the ſeparate ſalts, we can ſcarcely imagine it to hurt this Water.

The other fountains in this town are, in wet ſeaſons, nearly equal to this; but they vary ſo greatly, that it is almoſt impoſſible to aſcertain their properties; therefore, under ſuch difference and uncertainty, I ſhall not trouble my reader with the many analyſes which I have made of them.

FELON WATER.

ABOUT two or three miles from this town, on the ſouth ſide of the river, a large ſpring of fine bright Water riſes at the foot of an hill, juſt by *Felon-Hall*, belonging to *Charles Brandling*, Eſq; This Water is much admired for its taſte and colour; and is daily brought to this town upon horſes, where it is uſed chiefly for drinking and making of tea, amongſt ſome of the politer families.

Its ſpecific gravity is to that of rain Water as 134760 to 137421, the difference making $\frac{1}{3456}$ of the whole.

It ſparkled much in the glaſs, was very clear, and exceedingly pleaſant to drink.

It diſſolved ſoap ſlowly and without curdling, but does not lather well.

With lixivium of tartar it made no change at firſt; but, after four hours ſtanding, a ſmall cloud, and next morning a very little white precipitation.

With ſugar of lead a large white cloud and precipitation.

With aſh bark a blue colour, when held betwixt the eye and the light, when held oppoſite to the light, a green.

A gallon of this Water upon evaporation left $22\frac{768}{1000}$ grains of a duſky coloured reſiduum, which attracted moiſture very faſt and almoſt run per deliquium.

The reſiduum taſted aluminous and rather ſweet.

It turned ſyrup of violets to a light green.

With lixivium of tartar no change.

With the vitriolic acid a ſtrong ebullition, white fumes, and a peculiar ſmell, though ſomething reſembling the nitrous kind.

Five grains of this reſiduum upon the hot iron melted and bliſtered; afterwards calcined to a white powder, which weighed whilſt warm $2\frac{96}{100}$ grains.

The calcined earth in this part of the reſiduum was large in proportion, weighing $2\frac{53}{1000}$ grains, of a light grey colour.

FIG. VI.

The cryſtals when viewed through the microſcope, both before and after calcination, were very irregular; that marked (*a*) appeared in two or three obſervations of the uncalcined ſalt, but I ſaw nothing ſimilar to it after calcination; all the reſt were ſeen both in the calcined and uncalcined ſalt; and appear to me to be a mixture of the calcareous nitre and ſome aluminous kind of ſalt; but the ſmallneſs of the quantity prevented me from making any ſeparation, which could be ſatisfactory.

Though this Water is remarkably pleaſant to the taſte, and has been found by long experience to anſwer very well in the brewing of malt liquor; yet it is evident, from the above experiments, that it has ſome ſmall degree of hardneſs; but the quantity of ſalts are ſo exceeding ſmall, that it is almoſt impoſſible they ſhould betray themſelves to the taſte, and of ſuch a kind as we can ſcarcely ſuſpect of injuring the conſtitution; and even in waſhing, though ſomewhat more ſoap may be requiſite, it will be but a ſmall inconvenience. It is therefore of great uſe to the neighbourhood through which it runs; but, from the ſituation of the place, and want of a proper deſcent, it cannot conveniently be brought in pipes to this town.

WESTGATE-HILL WATERS.

SOME very fine ſprings of Water come from a hill-ſide, at the Weſt-end of this town, on each ſide of the military road leading to *Carliſle*, in the grounds of Mr *Anderſon*; which are very well ſituated, as to level, and would anſwer exceedingly well for ſupplying this town, in every reſpect but one, and that indeed a very material one, the quantity, which would ſcarcely be ſufficient for the whole town.

But a good deal of it is brought in carts to thoſe houſes which are neareſt to it, and it is found to be very good for brewing and all domiſtic purpoſes; though as this Water breaks out at three or four different places, it is not all of the ſame degree of purity. That which I have analyſed, is not, as I have reaſon to believe, the beſt of them; for another, upon

The calcined earth in this part of the reſiduum was large in proportion, weighing $2\frac{53}{1000}$ grains, of a light grey colour.

The cryſtals when viewed through the microſcope, both before and after calcination, were very irregular; that marked (*a*) appeared in two or three obſervations of the uncalcined ſalt, but I ſaw nothing ſimilar to it after calcination; all the reſt were ſeen both in the calcined and uncalcined ſalt; and appear to me to be a mixture of the calcareous nitre and ſome aluminous kind of ſalt; but the ſmallneſs of the quantity prevented me from making any ſeparation, which could be ſatisfactory.

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The ſpecimen which I tried ſparkled well in the glaſs, left no ochreous or other ſediment in its channel, was very clear and bright ; taſted cool, pleaſant and ſoft.

Its ſpecific gravity exceeded that of rain Water only by $\frac{1}{5863}$ of the whole.

It diſſolved ſoap uniformly, and readily, without any cloud or curdling, and lathered well.

With lixivium of tartar it made no change.

With ſugar of lead a very ſmall cloud, barely perceptible.

With powdered galls a bright amber.

With ſyrup of violets a duſky blue; but the next morning I imagined it rather altered towards a greeniſh caſt.

With aſh-bark a bright amber, with a green circle about the edge of the glaſs, when held betwixt the eye and the light; when oppoſite to the light, a very deep pea-green bordering upon a blue.

A gallon of it yielded, upon evaporation $28\frac{232}{1000}$ grains of ſediment, of a light colour, and a cool nitrous taſte.

This reſiduum made no ſenſible ebullition with ſpirit of vitriol; nor with lixivium of tartar; nor no pungent ſmell when rubbed either with crude ſal ammoniac or fixed alcali.

Upon the hot iron it neither melted nor crackled, nor could I perceive any fumes or ſmell: Five grains of it calcined to a white powder, which weighed, whilſt warm, $3\frac{18}{100}$ grains. The earth waſhed from this weighed $\frac{94}{100}$ of a grain.

The cryſtals were moſtly long, with four unequal ſides, and appeared jagged or broken at the ends, but ſome of them were irregular rhomboids, as (*a*).

FIG. IV.

The earth was evidently calcareous.

PUMP WATER.

THE Pump Waters in this town are moſt of them hard and unfit for ſeveral purpoſes; ſome of them indeed, which I have tried, are a little better than others; but, as the difference is not great, I ſhall only inſtance in one of the beſt and moſt in uſe, ſituated in *Weſtgate-ſtreet*, near the vicarage.

This Water when freſh taken is tolerably bright, and not very diſagreeable to the taſte. Several of the inhabitants in the neighbourhood think that it draws tea well, and gives it its full and agreeable flavour; but it leaves a very thick cruſt upon the inſide of a tea-kettle in which it is conſtantly uſed.

Its ſpecific gravity is to that of rain Water as 135023 to 134826, the difference 197 being nearly $\frac{1}{685}$ of the whole.

It reddens mutton and beef; but boils fiſh and greens well.

It crudles with ſoap, and makes no lather.

With lixivium of tartar, a white precipitate.

With ſolution of ſugar of lead, a ſtrong white precipitate.

With ſyrup of voilets, a faint green.

With galls, a deep amber.

With aſh bark, a light greeniſh blue at the ſurface; and after ſtanding ſome time, it ap-appeared blue all through.

A gallon of it upon evaporation left 88 grains of a light-coloured reſiduum, which is more by eight grains than Dr *Heberden* ever found in the pump Waters in *London* *; but as it attracted moiſture very faſt, the compariſon may be rather uncertain.

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* Medicial Tranſact. vol. I. p. 3.

It taſted a little pungent and nitrous, and was very gritty between the teeth.

It turned ſyrup of violets to a duſky green, and made a very ſlight effervescence with ſpirit of vitriol; but made no change in the lixivium of tartar.

Five grains of it upon the hot iron, firſt melted a little, then burned to a light aſh colour; and whilſt warm it weighed gr. $4\frac{385}{1000}$; ſo that it only loſt $\frac{615}{1000}$ of a grain in calcining.

The calcined earth appeared very white, and weighed gr. $2\frac{8}{10}$ being nearly half of the whole reſiduum, and was evidently burned into lime.

But upon examining the cryſtals, I was much ſurpriſed to find, that thoſe in the natural ſtate differed, very little, if at all, from thoſe which were calcined along with the other parts of the reſiduum; as I apprehended that the converſion of the ſelenite and calcareous earth into lime would have produced a new kind of ſalt different from the other; but all the variety ſeen in FIG. IX. was found in both. The greateſt part of them were flatted parallelopipeds and cubes as (*a*), and (*b*) and ſome very perfect hexangular priſms, as (*c*) All theſe had remarkably ſmooth ſurfaces, but I found none of them terminating in pyramids. Some of the ſmaller ones, at their firſt formation, appeared of a different kind, and collected into faſciculi, like bundles of ſmall rods tied at the middle as (*d*), and others were irregularly diſperſed as (*e*).

From all which it is evident, that this Water is loaden with nitre, ſome muriatic ſalt, and a large quantity of ſelenitical and calcareous earth. And we muſt from hence conclude, that the conſtant and long-continued uſe of it muſt be prejudicial to health, as it will have a direct tendency to form obſtructions, *&c.** and will be found very unfit for moſt domeſtic purpoſes.

OF RIVER WATER.

AS Rivers are chiefly compoſed of Waters from different ſprings, they might be expected, in ſome meaſure, to partake of the properties of thoſe ſprings and rivulets which run into them: The different ſoils or beds through which they run may likewiſe communicate ſome part of their contents to the Water; and hence we find that the Waters of ſome rivers have different properties; thoſe of the *Seine*, at *Paris*, for inſtance, are purgative, eſpecially to ſtrangers; the ſame is obſerved of the *Nile* at *Cairo*. Add to this the number of fiſhes and other animals, the leaves, bark and roots of trees, with a variety of vegetable ſubſtances which are found in moſt rivers; and near large and populous towns the quantities of filth and heterogeneous ſubſtances which are mixed with them; when we conſider all this, we are naturally led to imagine, that river Water would generally be very impure.

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* See page 22.

Yet nature generally provides a remedy againſt all theſe inconveniences; and it is a great inſtance of the goodneſs of providence, that thoſe Waters, which are moſt in quantity, the eaſieſt obtained, and moſt generally uſed, are rendered, by the courſe of nature, the moſt beneficial, and are beſt adapted to our health and convenience. For river Waters do, in a wonderful manner, very ſoon free themſelves from moſt of their impurities; they are in this reſpect, ſimiliar to rain Water, which in-

indeed makes a conſiderable part of their compoſition, that they naturally drop their ſediment, and are thus diſpoſed to a ſpontaneous analyſis*: That if the Water in a river were poiſoned in one place, I doubt not but that, in a very little running in its channel, it might become good and wholeſome. Though we may not fully comprehend all the means, by which rivers thus purify themſelves in their courſes, yet the following may deſerve our conſideration:

1. The motion of the current contributes to this effect. No Water which is kept in motion will putrefy; and the continued agitation of the parts, and their colliſions againſt one another often diſpoſe them to ſeparate, and thoſe mineral ones which naturally attract one another are, by theſe means, collected together, and by their ſpecific gravity depoſited. Hence the Waters in the moſt rapid rivers are ſaid to be comparatively light and pure, inſtances of which are given in thoſe of the *Rhine* and *Rhone*, which are very rapid moving rivers, and have their Waters lighter and purer than thoſe

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* See page 50.

of many others*, which leads me to a ſecond conſideration, and that is

2. The abſorption by the bed or channel of the river, whether this be ſand, marle, gravel, clay, or almoſt any other ſoil, it will attract many of the ſalts and other mineral, animal and vegetable ſubſtances, and diſunite them from the Water. The finer the mud is, the ſmaller the particles are, into which it is divided, and the more intimately and uniformly it is diſtributed through the Water, it will more effectually ſearch every part of it, catch hold of whatever comes in its way, and carry it to the ſides and bottom: And hence the Waters of the muddieſt rivers, after they have properly ſubſided in ciſterns or reſervoirs, are often the pureſt and brighteſt.

3. In the courſe of Water through the channels of rivers, the ſun and air have a conſiderable effect in rendering it more pure.

If Water be a little hard, it is well known to become ſofter by being expoſed to the ſun and air: By what mechanical operation this is effected, or how it can be accounted for, may af-

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* *Rutty*'s Synops, p. 15.

afford matter of ſome diſpute; perhaps the heat may contribute not a little towards it; for we ſee ſome Waters which are loaden with contents, that will depoſite a great part of them, eſpecially of the earthy ones, upon being moderately warmed: And it is probably upon this account that ſome Waters become ſofter, milder, and more agreeable upon boiling, by dropping thoſe earthy or calareous parts, which were rather ſuſpended than diſſolved in them*. But ſuch Waters as are loaden with fixed ſalts, will generally be found more ſtrongly impregnated after boiling.

Upon this account thoſe rivers which take the longeſt courſe are thought to afford the beſt Water, as they are more and longer expoſed to the ſun and air. So the Water of the *Ganges* has, by ſome, been reputed the beſt in the world; and upon this account, I think I have ſomewhere heard, that the eaſtern monarchs have been at the expence of carrying it to a very great diſtance. To this cauſe *Proſper Alpinus* attributes, in a great meaſure, the ſuperior excellence and purity of the *Nile*†;

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* *Percival's* Exper. and Obſerva. p. 27.

† Med. Egypt. lib. I. cap. 10.

which river takes its riſe nearly under the *Tropic* of *Capricorn*, and running through the whole breadth of the torrid zone, empties itſelf into the *Mediterranean*, in the latitude of about 32 deg. north; during which long and hot courſe, it is almoſt boiled by the ſun, precipitates its contents, is attenuated and cleared of all its impurities.

The particular colour and taſte which river Waters contract from vegetable ſubſtances, are indeed more permanent; ſome of the inhabitants of *London* have complained of the new river Water in this reſpect, eſpecially in the autumnal ſeaſon, when a great many leaves of trees are blown into it; but I do not remember to have obſerved this particular taſte in it, though I have uſed it conſtantly for ſome time.

THAMES WATER.

THE Waters of ſome rivers are very apt to putrefy, eſpecially in the ſummer time. That of the *Thames* is ſaid to become offenſive in ſeven or eight days, or ſometimes ſooner, eſpecially when it is kept in unſeaſoned caſks;

in this ſtate it generates a quantity of foul inflammable air, as may be ſeen by holding the flame of a candle to the bung hole of a caſk, when it is firſt opened. But by this fermentation it ſoon purifies itſelf, and by opening the bung it will often become ſweet in twenty-four hours, and ſooner if it be much ſhaken, or poured to and fro:* The ventilating it has likewiſe been uſed with ſucceſs in ſeveral of our ſhips; and at *Deal* and other places, very cheap and convenient ventilators are ſold in the ſhops, for this purpoſe, conſiſting only of a pair of bellows going into a tin tube, with a head full of holes like that of a watering-pot, which tube being put to the bottom of a jar or pail of ſtinking Water, and freſh air blown through it, the Water becomes ſweet and good in a very little time.

Many of our ſhips in the coal trade take in the *Thames* Water near *Billingſgate*; and ſuch of it as I have ſeen, when brought to *Newcaſtle*, is exceedingly bright, ſoft, and well taſted. Its ſpecific gravity was very little more than that of filtered rain Water, being as 1347893 to 1347500; and the difference 393 being only $\frac{1}{3429}$ of the whole: Notwithſtanding which it made a thick white cloud and precipitation with a ſolution of ſugar of lead; and a very faint cloud with lixivium of tartar.

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* Hales's Philoſophical Exper. p. 58.

It diſſolved ſoap readily, and lathered well.

With galls it turned a bright amber colour, and with aſh bark a ſudden ſtrong green.

A gallon of it upon evaporation yielded gr. $31\frac{452}{1000}$ of a brown ſediment; the taſte of which was ſaline, and rather auſtere.

It the sediment effervеſced very ſtrongly with ſpirit of vitriol, and emitted white fumes.

Five grains of it crackled and melted a little upon the hot iron; and afterwards burned to a grey powder which weighed gr. $3\frac{51}{100}$; and the calcined earth ſeparated from this weighed gr. $2\frac{49}{100}$, it effervеſced and partly diſſolved in very ſtrong ſpirit of vitriol.

Some of the cryſtals when viewed through the microſcope, appeared like broken pieces of glauber ſalt, as *(a)* and *(b)*; others were collected into irregular lumps, one of which is exactly repreſented in the figure at *(e)*; and a good many cubical cryſtals, of the muriatic kind, ſeparate, and diſtinct from the reſt, appeared preciſely in the ſame manner with thoſe in the ſeventh figure.

FIG. VIII.

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From which it appears, that a gallon of the Water contains gr. $22\frac{6}{100}$ of reſiduum, in the ſtate in which it came off from the hot iron; of which about fifteen grains and an half were abſorbent and calcareous earth; and only about ſix grains and a half of muriatic and nitrous ſalt.

As this Water is ſo well known, I thought it unneceſſary to make any farther experiments or obſervations upon it, and theſe above mentioned will help any one, who has the curioſity to compare them, to bring the other Waters to the ſame ſtandard.

TYNE WATER.

AS the Waters in moſt of our navigable rivers are affected by the tides, and other circumſtances, it may not be improper to give a ſhort ſketch of ſome particulars relating to the natural hiſtory of this river, which may be ſuppoſed to alter the property of its Waters at different times, before we proceed to relate our experiments upon it.

The river *Tyne* riſes from different ſources;

ſome of them about ſixty miles to the north weſt, and others about fifty to the weſt and ſouth weſt from this town; and from hence to its entrance into the ſea at *Tynemouth*, is about ten miles; but if we meaſure by the windings of the river it will be more in both caſes: So that its ſeveral branches ſpread over a very large tract of country, the greateſt part of which abounds with collieries and lead mines,* from the numerous levels and engines of which, immenſe quantities of Water are conſtantly flowing in: That we ſhall be much within compaſs if we aſſert, that above half of the Water which runs by *Newcaſtle* comes from the mines; and ſometimes the waſte Waters above mentioned,† will be ſuddenly let off in very large quantities, or what the workmen call huſhes, and will apparently diſcolour the river, for a conſiderable ſpace. Yet ſo readily and entirely does the river clear itſelf from any impurities, which it might be ſuppoſed to contract from hence, that I have never been able to diſcover the leaſt particle of any vitriolic or other ſubſtances, which are to be found in the coal Waters; though I have repeatedly and very carefully examined it at different ſeaſons of the year, and different times of the tide: Indeed I apprehend that we are much indebted to the tides for rendering the river Water ſo pure and good, as it unqueſtionably, is in this neighbourhood; and the particular courſe and channel of the river contribute, not a little, to this effect.

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* p. 57. † See note, in p. 75.

The channel, betwixt *Newcaſtle* and *Tynemouth*, is of a very different width and depth; ſo that the tide is more rapid in ſome places than in others. The entrance into the harbour at the *Low-Lights* is very narrow; but the channel forms into a fine large baſon, for the whole length of *Shields*, capable of holding above two thouſand ſail of large ſhips; above which the tide ſpreads over the extenſive flats of *Jarrow-Slake*; and then, for a great length, forms a remakably fine, broad and deep pool, called the *Long-Reach*, all which contain an immenſe quantity of Water. After this the tide is obſtructed by ſeveral windings and narrow places in the channel, till it comes within about a mile of *Newcaſtle*; where it runs in an open and wider pool, till it flows about two miles above this town, when it is a good deal interrupted in its courſe by a large iſland, conſiſting of many acres, called the *King's Meadows*: After flowing round this iſland by two narrow channels, and through ſeveral beautiful windings, it riſes a little above the village of *Newburn*; in all about ſeven or eight miles above *Newcaſtle*.

The tides commonly flow about four hours and an half, and ebb about ſeven hours and an half, at *Newcaſtle-bridge*: And the perpendicular riſe of the river here, in a ſpring tide, will ſometimes be about eleven or twelve feet, and at *Tynemouth* bar, about eighteen feet; but both theſe circumſtances vary greatly from the different winds, and the different quantities of freſh water in the river: In a north-weſterly wind they will ſometimes riſe three feet higher than I have mentioned; and, in a ſouth-eaſterly one, ſometimes ſcarcely half ſo high: And, in ſome of our great land-floods, the tide has not ſufficient force to ſtem and turn the current, which will ſet downwards during the whole ſwell of the tide.

From this ſhort account we may judge, in ſome meaſure, of the natural effect of the tides upon the water in this river. For, by the conſtant and contrary motions which are given to the Waters, by the flux and reflux of the tide, the mud is ſtirred up, the ſalts and other impurities mixed with part of it, and carried into the the ſea; whilſt that which ſubſides in the channel is left unſaturated with ſalts, cleaner from impurities, and readier to attract and abſorb any freſh ones that may come in.

The mud thus ſtirred up, is indeed ſometimes long in ſubſiding; as, upon land floods eſpecially, it chiefly conſiſts of a fine light clay, divided into ſuch minute particles, that a great deal of it will paſs through a common filtering paper, and make the Water a little wheyiſh; but this will in time ſeparate and leave the Water remarkably bright and pure; and this very inconvenience is, for the reaſons aſſigned above, attended with a ſuperior advantage.*

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* We are told that the Water of the *Nile* muſt ſtand for ſome days, before it become perfectly bright; and that it was a cuſtom at *Cairo*, to rub the ſides of the veſſels in which it was contained with a few bruiſed almonds, by which means it ſubſided ſooner.

Another effect of the tides is, that they may ſometimes bring up a little ſalt Water. In ſummer time, when the river is low, and the influx of the tide meets with leſs reſiſtance, the Water will be a little brackiſh at *Newcaſtle*; but that is only about the time of high water; for at half ebb, or half flood, it has ſcarce any ſenſible proportion of ſalt in its reſiduum; and in winter time, or indeed in the neap tides in ſummer, we can ſeldom find the leaſt brackiſhneſs by the taſte. When we conſider, from the above account, the immenſe quantity of freſh Water that muſt be driven back, before the tide can riſe to *Newcaſtle*, it will appear ſtrange that any ſalt Water ſhould ever reach above our bridge. I have often found a ſenſible difference in the taſte of the Water which was taken up below the bridge, from what was taken up above; the force of the tide being a good deal broken by the pillars. I have not indeed analyſed it in the drieſt ſeaſons; but the day in which I am writing this, I tried the ſpecific gravity of ſome of it which I took up at high water, in the laſt ſpring tide, after a long droughty ſeaſon, and found it conſiderably heavier than any which I had tried before; for it differed from rain Water by $\frac{1}{156}$ part of the whole: whereas in winter it rarely differs by $\frac{1}{1000}$. I likewiſe, at the ſame time, tried ſome which I had taken up at *Shields*, and found it to differ from rain Water by above the 28th part, which is heavier than moſt of our tables make ſea Water to be. Indeed, from the freſh Water which is driven back, the ſaltneſs muſt decreaſe all the way, as the tide comes up the channel; till, a little above this town, it becomes quite evaneſcent; and, for ſeven hours out of every twelve we have ſcarce any ſalt at all, as will appear more fully preſently.

Another effect of the tide upon this, and indeed upon moſt navigable rivers, is, the immenſe ſhoals of very ſmall fiſhes which are driven up in the later ſummer months. It has been frequently obſerved here, that a pint of Water cannot be taken up near the ſhore, any where within the compaſs of the tide, but it will contain ſeveral hundreds of them; nay they will frequently lie ſo thick, that we cannot, even in very ſhallow places, ſee the bottom of the river for them. The Water which is taken up ſo filled with theſe little animals, is indeed unfit for dreſſing of victuals, brewing, or almoſt any other purpoſe; for it has from the firſt a fiſhy diſagreeable taſte, and very ſoon putrefies: But all theſe little animals are within two or three yards of the ſhore, and moſtly in ſtill water; for a ſmall current ſweeps them all away; and, upon a freſh flood coming down the river, not one of them is to be ſeen: Conſequently they can be no objection to the ſupplying this town with Water from the river, as the Water might eaſily be brought to the pumps of an engine without conveying any of them along with it.

I ſhall not trouble my reader with a tedious relation of all the diffierent experiments, which I have made upon this Water; but ſhall ſelect two trials, one of which was made of the Water taken up at half ebb, and the other at high water, when the river was in its moſt uſual ſtate: In the firſt of them indeed, which was taken up on the 24th of January, 1770, the river was rather more muddy than uſual, and I allowed the Water to ſtand two days before I weighed it.

Its ſpecific gravity was to that of rain Water as 1348481 to 1348145; the difference being 336, or nearly $\frac{1}{4013}$ of the whole.

Its taſte was mild, cool and agreeable.

It made no change with the lixivium of tartar, or ſolution of ſugar of lead; nor yet with galls, ſyrup of violets, or acids.

A gallon of it left upon evaporation only *gr.* $4\frac{56}{100}$ of a light brown ſediment; which taſted evidently, though ſlightly, ſalt; and felt gritty betwixt the teeth.

The quantity of this reſiduum was ſo very ſmall, that it ſcarcely afforded an opportunity of ſeparating the ſalt from the earth, or of trying any other experiments; and upon ſome other evaporations of the Water, taken up at half flood and half ebb, the reſiduum was ſtill leſs; ſo that I looked upon any minute examination of them as trifling and inſignificant.

On the 29th of *January* 1770, I took a quantity of Water from the river, at the weſt end of the town, juſt at the time of high Water, in a ſpring tide. The weather was then dry and remarkably warm for the ſeaſon, and the Water much brighter than that which I uſed in the laſt experiment; and I think had no brackiſhneſs diſcoverable by the taſte: But it turned quite milky and precipitated, upon dropping in a little ſolution of ſugar of lead.

A gallon of it left, upon evaporation, *gr.* $19\frac{76}{100}$

of a light brown reſiduum, which taſted very ſalt, crackled upon the hot iron; made an ebullition and white fumes with ſpirit of vitriol, but no apparent change in ſyrup of violets, and attracted moiſture very faſt.

Five grains of it were, by the hot iron, reduced to $4\frac{15}{100}$, but increaſed again in weight ſo faſt, that I could not be ſo exact as I could have wiſhed.

After it was well waſhed in diſtilled Water, it left a dark grey inſipid powder of calcareous and abſorbent earth, which weighed *gr.* $1\frac{362}{1000}$.

The ſalt was entirely muriatic; and the cryſtals when viewed through the microſcope appeared as in FIG. VII.

The ſalt was in proportion to the earth as 3638 to 1362; ſo that each gallon of this Water contained $14\frac{378}{1000}$ grains of ſalt, and $5\frac{382}{1000}$ of earth.

Obſ. Though this Water was manifeſtly brighter than that which was uſed in the preceeding analyſis, yet the earthy parts of it were more than the whole reſiduum of the other; and I am ſure that they were both collected and weighed with equal care: Which ſhews that the tides impregnate the Water in this river with ſomething more than ſalt; or the ſalt may probably be a means of uniting more earth with the Water; but theſe ſubſtances are, in a very little time, either moſtly carried away or ſpontaneouſly precipitated.

Upon analyſing ſome Water, taken up in another ſpring tide, I only obtained *gr.* 12 $\frac{968}{1000}$ from a gallon; but in very dry weather, when perhaps not one third part of the freſh Water comes down the river, an high tide may bring up a larger proportion of ſalt; as indeed is evident from the ſpecific gravity of the *Tyne* Water taken this day. But in general, or at leaſt for above eight months in the year, it contains no ſalt, even at high Water, that can be any way prejudicial: And when we conſider, that from half ebb until half flood, or for upwards of ſeven hours out of twelve, there is ſcarcely any perceptible ſalt in it, no reaſonable objection can be made, upon this account, againſt ſupplying the town with it; as an engine might work, very well, above fifteen hours in the day; and in that time, with the greateſt eaſe, it might raiſe four or five thouſand hogſheads to the higheſt part of the town.

The contents of this Water are ſo ſmall in quantity, and in their nature ſo very inoffenſive, that they are by no means worthy of conſideration: And the other objections, which have been made to it, are equally trifling and inſignificant. It has been ſaid that it gives both meat and linen a bad colour; ſo will the *Thames* Water, or that of almoſt any river in *England*, if it be uſed before it has ſubſided; but ſeveral families in this town who keep it in proper ciſterns make no ſuch complaint, and ſome of it which I have now by me, and which was taken up quite muddy, is as clear and bright as any Water which I know. The force of the pumps, the conveyance through pipes, and the reſting in large reſervoirs, will all undoubtedly contribute to render it bright and pure. It is known to keep exceedingly good and ſweet through long voyages, as it has been frequently carried to *North-America*: And what is ſtill a farther argument for the ſupplying of this town with it, it is a ſource which can never fail, and indeed the only one which can ſafely be depended on: For the opening of new collieries, and the extending of old ones, often make ſtrange alterations, in the courſes of ſeveral ſprings in this neighbourhood.

OF

OF STAGNANT WATERS.

THE ſtagnant Waters in lakes, ponds and ditches, are generally eſteemed the worſt; and by the experiments of *Hoffman*, *Boerhaave*, and others, they appear to be ſpecifically the heavieſt: But we muſt be cautious of drawing too general inferences, even from the reports of theſe two great men; for *Hoffman* tried the ſpecific gravity of the marſh Water taken out of the town ditch at *Hall*, by an hydrometer, which he tells us exceeded the common ones;* and *Boerhaave* draws his concluſions from the lake of *Harlem*: † Both theſe Waters are very impure; for that at *Hall* was full of inſects and contained a quantity of alcaline ſalt; and *Boerhaave* tells us, that all the dirt and filth from the populous city of *Leyden*, beſides the myriads of pounds of dying ſtuff, alum, tartar, vitriol, *&c.* which are mixed with Water, and thrown out in whole floods from the dyers veſſels, are all emptied into the lake at *Harlem*; and the perfection to which ſeveral colours are brought at *Leyden*, he aſcribes to this particular Water; becauſe he ſays, that the dying of thoſe colours has been in vain attempted in other places, though by the ſame workmen, and after the ſame manner. It is evident, from theſe accounts, that both theſe Waters have ſomething peculiar in them, and that, from their ſpecific gravity, no general concluſion can fairly be drawn.

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* Obſervat. phyſico. chymic. lib. II. Obſ. 7.

† Element. chem. vol. I. p. 612.

The Water in ſome of our lakes in this iſland is, I apprehend, as pure and good as moſt of what we ſhall find elſewhere. I pretend not indeed to have analyſed many of them, nor even to have tried their ſpecific gravity; but I remember well to have drank of the Waters in *Winander-mere*, *Uls-water*, and others of our large lakes in *Weſtmoreland* and *Cumberland*, and have found them very ſoft and good: And I look upon it to be a ſtrong proof of their ſalubrity, that fiſhes, of various kinds, are caught in as high perfection, in the two lakes abovementioned, as any where in the world. For beſides the numbers of that beautiful and elegant fiſh the charr, which are annually taken out of them, and almoſt peculiar to them; I believe they may challenge the world to produce finer trout, perch, or any other fiſh which they contain: And the purity of Water will be allowed to be as neceſſary to the health of theſe animals, as that of the air is to ours.

But ſtill theſe are but particular inſtances, nor indeed can thoſe larger lakes come ſo properly under the denomination of ſtagnant Waters; for, as ſome of them extend to the ſpace of perhaps ten ſquare miles, the wind keeps them in almoſt conſtant and perpetual agitation; and though we find no ſenſible current, eſpecially in the broader parts of them, yet they are ſupplied by ſmall rills, which trickle down the adjacent mountains, and have a ſmall outlet at the bottom. But where the ſtagnant Water is confined to a narrower compaſs, and the ſurface conſequently leſs agitated by the wind; where there is no renovation of the Water, or where the ſupply is only from the drains of towns, or the brown, and ſometimes almoſt black Water from moraſſes, the caſe is widely different: Such Waters as theſe muſt neceſſarily contain a great quantity of heterogeneous matter, and will ſoon putrefy. So that I doubt not but *Hoffman* and *Boerhaave* were prefectly right in their obſervation; all I contend for is, that there may be as great, or perhaps a greater variety in the Waters of lakes, ponds and little ſtanding pools, than we find in ſprings or rivers; and that this increaſed ſpecific gravity is by no means a general characteriſtic of them, as I ſhall ſhew in the inſtance of the laſt Water, which I intend to examine at preſent.

GATESHEAD FELL WATER.

UPON the top of Gateſhead fell, near the road from hence to Durham, is a pretty large collection of ſtagnant Water, from which a part of this town has been ſupplied for ſome years: As this is moſtly rain Water falling upon the flat, or rather hollow, top of the hill, in wet ſeaſons it is generally very good; for a great part of its impurities are depoſited in the ponds, reſervoirs, and pipes, and it comes into ſome private houſes, almoſt as pure, though not ſo well taſted, as filtered rain Water: But, in dry ſeaſons, it is often entirely loſt, or its place ſupplied with ſome coal Waters from the neighbourhood; ſo that it is ſeldom of equal purity for any long time together: And, what is ſtill a greater inconvenience, the reſervoirs are fixed ſo low, that the Water will not riſe into the higher ſtreets; upon which account, half the town is not ſupplied with it.

The part of it upon which I made the following trials, was taken from a ciſtern in a private houſe, on the 25th of July laſt, after a wet ſeaſon.

It was not very bright, nor quite agreeable to the taſte, but ſoft and ſmooth.

Its ſpecific gravity was to that of rain Water as 134826 to 134765, the difference 61 being about $\frac{1}{2210}$ of the whole.

It diſſolved ſoap very even, and lathered well.

With ſolution of ſugar of lead, and with lixivium of tartar, no change.

With powder of galls, it made a pale amber colour; and with aſh bark, a deep amber, when held betwixt the eye and the light, but when oppoſite to the light, a blue circle at the top.

A gallon of it, upon evaporation, yielded *gr.* $8\frac{776}{1000}$ of an aſh coloured ſediment, which taſted auſtere and vitriolic, and attracted moiſture very faſt.

Upon the hot iron, it melted and ſmoaked, but without any ſenſible ſmell. Five grains of it burned into a hard lump which weighed, whilſt warm, $3\frac{34}{100}$. The earth waſhed from the ſalt, was perfectly inſipid of the argillaceous kind, and weighed $\frac{84}{100}$ of a grain.

The cryſtals were unequal parallelopipeds, with ſcabrous ſurfaces; and all of them which I ſaw appeared broken at the ends: They are exactly repreſented in FIG. X.

From the whole it appears that a gallon of this Water produced of the entire reſiduum *gr.* $8\frac{776}{1009}$; of which $2\frac{914}{1000}$ were moiſture, or volatile parts, $4\frac{408}{1060}$ fixed ſalts, and $1\frac{454}{1000}$ inſipid earth; the quantity of each being ſo ſmall as to render it almoſt inſignificant.

CONCLUSION.

I HAD once determined to have ſubjoined ſynoptic tables to this treatiſe, after the manner of Dr *Rutty*, by which the different appearances might have been exhibited at one view: But as I found that it would have increaſed the book by at leaſt a ſheet and an half, and would only have been a recapitulation of what is ſaid before, and what the reader may eaſily turn to, if he want to compare one analyſis with another, I judged it unneceſſary.

As this deſign was originally undertaken for the ſatisfaction of the magiſtracy and inhabitants of this town, upon ſome late propoſals for furniſhing them with Water; it may be expected, that I ſhould ſhew which Water is the beſt and fitteſt for that purpoſe; but I ſhall trouble my reader very little farther with thoſe compariſons: If what is ſaid above be allowed, The *Tyne* Water is undoubtedly the beſt and fitteſt in all reſpects; and next to it the ſprings in *Weſtgate-Hill*, and thoſe from which the fountain near Sir *Walter Blackett*'s is ſupplied. There are ſeveral other Waters in this neighbourhood, which are well deſerving of the naturaliſt's attention; but I have not as yet had leiſure or opportunity to try them all: What attempts I may hereafter make towards a more complete natural hiſtory of the minerals and Waters in this neighbourhood, I cannot at preſent ſay. The great variety of very different minerals which we have in this country, and their influence upon the Waters are ſubjects which, from their great importance, cannot be too minutely attended to. That ſome of theſe minerals are ſtrong and active poiſons, I have already ſhewn; and, before I part with my reader, I ſhall ſo far anticipate what I had deſigned for the ſubject of a future treatiſe, as to inform him that there are, in many parts of this country, great varieties of true and genuine arſenical ores; that we have the real cobalt in large quantities, that this mineral abounds with arſenic, and that even in its natural ſtate it is poiſonous. In ſuch ſituations the examination of new and unknown Waters is no light nor trivial matter; for the experience of a whole age is ſcarcely adequate to ſo important a deciſion.

FINIS.

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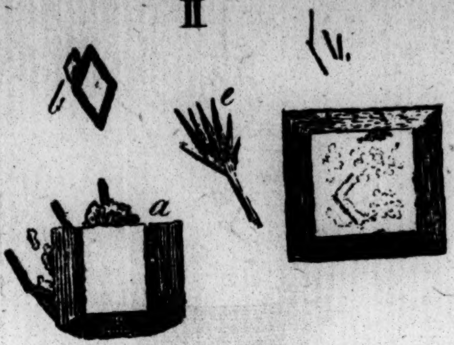
II



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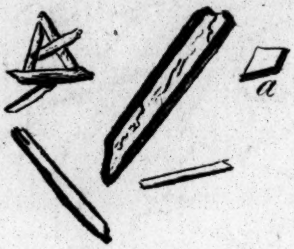

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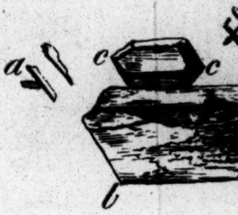

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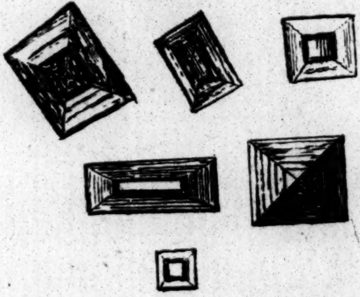

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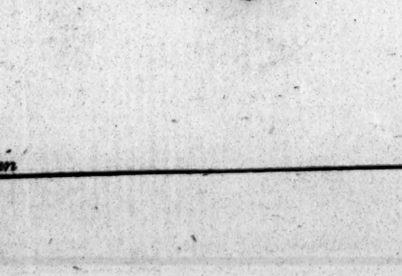

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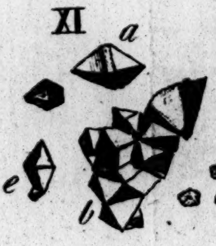

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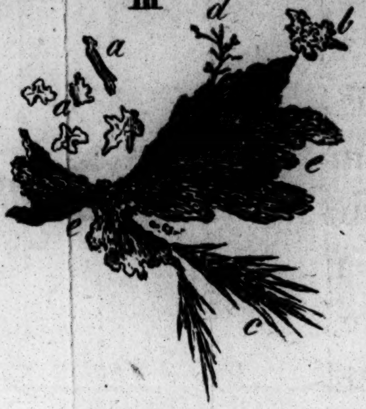
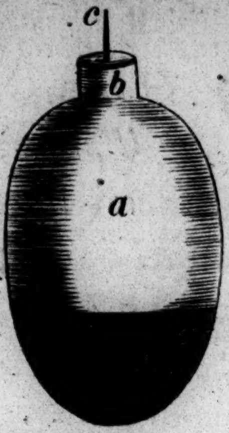


Fig. I.



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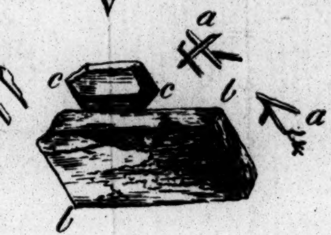

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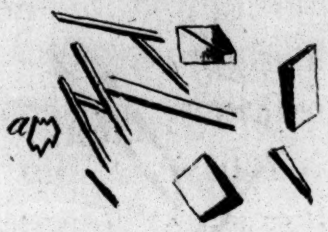

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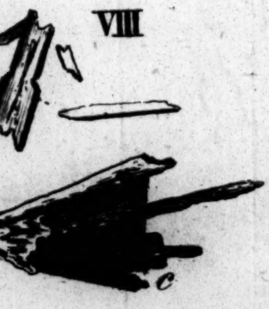

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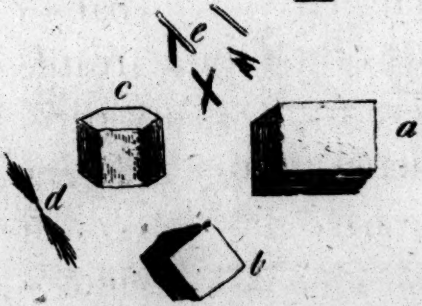

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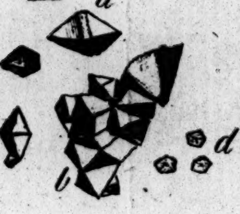

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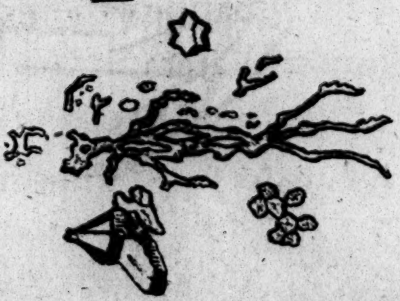

R. Beilby Sculpt.